Clement

ISLA MONA

VOLUMEN II

ESTADO LIBRE ASOCIADO DE PUERTO RICO / OFICINA DEL GOBERNADOR / JUNTA DE CALIDAD AMBIENTAL

ESTADO LIBRE ASOCIADO DE PUERTO RICO OFICINA DEL GOBERNADOR
Junta de Calidad Ambiental

Las Islas de Mona y Monito
Una Evaluación de sus Recursos Naturales e Históricos

Mona and Monito Islands
an Assessment of their Natural and Historical Resources

Volumen II

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The Climate of Mona Island

By

Robert J. Calvesbert

Climatologist for Puerto Rico and Virgin Islands
NOAA - National Weather Service

GENERAL

The climatic regime of Mona Island results from a number of relatively complex controls of which the primary are atmospheric, oceanic and geographic. It is unfortunate that the complete interplay of these factors can not be adequately described and interpreted due to the restriction imposed by data limitations. It appears certain, however, that the balance between these controls is a delicate one and over a long time period may be the ultimate mechanism responsible for optimum equilibrium between plant, animal and human habitation of the island. Atmospheric sampling on Mona has been limited to the measurement of daily rainfall amounts only. As a result, the climatologist is forced to deduce much of the island's climatic character from other means. Stone[1] has pointed out that in the absence of extensive systematic instrumental observations of the climatic elements, the "climax vegetation" may serve as a rough indication of the climatic type. Climax vegetation has been defined by Blumenstock and Thornthwaite[2] as the virgin growth which represents the most luxuriant vegetation group made up usually of several species, which have adjusted to the climate of the region in question. For example, in the absence of temperature data, one of the more important climatic parameters, the association of that portion of the Puerto Rico south coast with similar vegetative cover and rainfall regime would seem to provide a reasonable guide towards developing a heat index needed for formulating the potential evapotranspiration estimate used in this report. However, the size, topography and geographical location of Mona subject it to unique environmental influences as compared to Puerto Rico. The small land mass and low topographic profile produce climatic characteristics approaching more nearly that of the surrounding ocean. Located at about the same latitudinal position and midway between the Dominican Republic and Puerto Rico, on the southern edge of the Bermuda High Pressure Cell, Mona is subject to an uninterrupted flow of the easterly trades throughout the year. On the other hand, the westerly position permits the passage of more wintertime polar outbreaks and probably accounts for the relatively higher rainfall amounts in the winter months compared to Puerto Rico and probably a greater temperature range. The subject of possible climatic change in view of the apparent decrease in soil fertility and available water supply on the island is of academic interest and not pursued in this report.

THE WATER BALANCE AND CLIMATIC CLASSIFICATION

The dryness of Mona, considering its location deep within the tropical marine environment, is a paradox to the casual observer. To differentiate the local climate of Mona on the basis of any of the presently accepted classification systems, one must infer certain parameters from the bordering land masses of Puerto Rico or Dominican Republic. The classification scheme followed here is that of Thornhtwaite's "Second" classification of climate[3]. This method is based on a physical concept of water balance and potential evapotranspiration. For the purpose of this report, only the moisture index, I_m, was computed along with its subdivision to define the moisture province in which Mona is classified. The approach defines climate on

the basis of average annual potential evapotranspiration (i.e., water need) expressed in terms of a moisture index,

$$I_m = \frac{1}{e}(100s - 60d)$$

where e is the water need, s is the water surplus and d is the water deficiency.

Because of the lack of temperature data for Mona, the water need was developed from that south coast portion of Puerto Rico which has the most similar rainfall regime and vegetative cover. The mean monthly water need versus the mean monthly precipitation (p) indicates a monthly deficit during the entire year as shown in Text Table 1.

Text Table 1
Monthly Water Balance

p	*JAN.*	*FEB.*	*MAR.*	*APR.*	*MAY*	*JUNE*	*JULY*	*AUG.*	*SEPT.*	*OCT.*	*NOV.*	*DEC.*	*ANN*
p	1.56	1.11	1.23	2.04	3.18	2.85	2.60	3.21	3.16	4.36	3.42	3.13	31.85
e	3.79	3.52	4.29	4.90	5.84	6.18	6.47	6.30	5.82	5.64	4.85	4.27	61.87
d	2.23	2.41	3.06	2.86	2.66	3.33	3.87	3.09	2.66	1.28	1.43	1.14	30.02

Based on the data shown above it is evident that under normal rainfall conditions there is no season or month of the year with a water surplus in excess of the water need and therefore the moisture index is based completely on the water deficiency or aridity portion of the term. In this case:

$$I_m = \frac{1}{157} -60\ (76.3) = -29.1$$

where water amounts are in centimeters. Tables of Thornthwaite's moisture province and subdivision classifications are presented in Text Tables 2 and 3.

Text Table 2
Thornthwaite's Climatic Types by Moisture Provinces

Type	*Moisture Index*	*Symbol*
Perhumid	100	A
Humid	80 to 100	B_4
Humid	60 to 80	B_3
Humid	40 to 60	B_2
Humid	20 to 40	B_1
Moist subhumid	0 to 20	C_2
Dry subhumid	-20 to 0	C_1
Semi arid	-40 to -20	D
Arid	-60 to -40	E

For dry climates (i.e., moisture provinces, C_1 D, and E), the subdivisions are defined in terms of an index of humidity, $I_h = 100s/e$. For Mona, $S = 0$ or $i_h = 0$

Text Table 3
Thornthwaite's Climatic Moisture Subdivisions

Subdivision	I_h
d = little or no water surplus	0 - 10
s = moderate winter water surplus	10 - 20
w = moderate summer water surplus	10 - 20
s_2 = large winter water surplus	more than 20
w_2 = large winter water surplus	more than 20

Mona Island therefore falls within the *Semi arid* classification with little or no water surplus (type D_d). The estimate of a mean annual water deficit of about 30 inches is probably on the conservative side since use of the mean monthly data in the water balance results in underestimation of the water deficiency within arid and semi arid zones as compared to computing the individual years. However, the difference is not significant enough to change the climatic classification.

THE RAINFALL REGIME

Rainfall is one of the climatic elements which most concerns the planner as well as other environmental analysts studying the development potential of Mona Island. Regular observation of daily rainfall began in January 1918 and has continued to the present with several breaks in the observing record. The observations have been made by members of the U.S. Coast Guard from a raingage located adjacent to the light house at an elevation of 173 feet above the sea level. The data is published in *Climatological Data* —Puerto Rico and Virgin Islands. For the purpose of this report a selected period of record was used based on the following criteria:

1. The period of record is for the standard climatological period nearest to that defined by the World Meteorological Organization. This consists of the 30 years ending with the most recent decade year. Therefore, the new standard period will be 1941 - 1970. Because of observing breaks for the years 1938 and 1943 thru 1946, it is necessary to use the period from 1936 to 1970 for Mona Island data.
2. No years with more than two missing months of data were used.
3. The period of record had to be heterogeneous (observations made from same site location.

Text Table 4 presents the resulting long term (30-year) mean monthly and annual rainfall amounts for Mona as used in this report.

Text Table 4
Mona Island Mean Monthly and Annual Rainfall (Inches)

JAN.	*FEB.*	*MAR.*	*APR.*	*MAY*	*JUNE*	*JULY*	*AUG.*	*SEPT.*	*OCT.*	*NOV.*	*DEC.*	*ANN.*
1.56	*1.11*	*1.23*	*2.04*	*3.18*	*2.85*	*2.60*	*3.21*	*3.16*	*4.36*	*3.42*	*3.13*	*31.85*

For a similar period of record, the mean annual total rainfall for Mona is compared to selected stations on the south coast of Puerto Rico and the south coast divisional average in Text Table 5.

Text Table 5

STATION	*MEAN ANNUAL RAINFALL (Inches)*
Mona Island	31.85
Central San Francisco	32.73
Ensenada	29.88
Ponce	34.49
Santa Isabel	33.33
Santa Rita	33.11
South Coast Division	35.26

The mean annual amount 31.85 inches is significantly lower than previous values quoted for Mona which ranged around 38 inches. Partly, this is due to a different period of record which contains suspect data and several severe hurricane passages which bias the data. The period chosen for this report is considered representative of that rainfall contributed by normal convective and synoptic activity over a long term.

It would appear on the basis of these data that the overall moisture province of Mona resembles the area around Guánica and Guayanilla on Puerto Rico's south coast. The similarity in the general vegetative cover further supports this conclusion. However, there is a difference in the seasonal rainfall variation between the two areas. Text Table 6 compares the mean monthly rainfall between Mona and Central San Francisco in the Guánica area. It is evident that there is a more uniform pattern at Mona with more rainfall during the drier season months of December, January, February, March and April and less rainfall in the late summer and Fall months.

Text Table 6
Mean Monthly and Annual Rainfall (Inches)
Mona Island vs. Central San Francisco

JAN.	*FEB.*	*MAR.*	*APR.*	*MAY*	*JUNE*	*JULY*	*AUG.*	*SEP.*	*OCT.*	*NOV.*	*DEC.*	*ANN.*
Central San Francisco												
0.94	1.00	0.79	1.75	3.14	2.68	2.55	4.38	6.00	5.54	3.51	1.20	33.48
Mona Island												
1.56	1.11	1.23	2.04	3.18	2.85	2.60	3.21	3.16	4.36	3.42	3.13	31.85

Monthly and annual probabilities of rainfall for Mona are presented in Text Table 7. The method used for computing these probabilities is based upon fitting the data from selected 30-year period of record to the Gamma Distribution according to Thom's[4] technique. If water needs are known for a particular enterprise, these data will assist the planner in determining the chance of success for an operation affected by precipitation.

Text Table 7
Rainfall Probabilities

Month	Probability - inches		
	9/10	5/10	1/10
January	0.3	1.3	3.2
February	0.0	0.8	2.6
March	0.2	1.0	2.5
April	0.3	1.6	4.3
May	0.9	2.7	6.0
June	0.7	2.4	5.5
July	0.6	2.2	5.2
August	0.8	2.7	6.3
September	0.8	2.8	6.0
October	1.3	3.8	8.2
November	1.3	3.1	6.0
December	0.7	2.6	6.2
Annual	23.2	31.3	41.2

Of additional interest is an accounting of the average number of days per month of rainfall as compared to similar Puerto Rico south coast stations. Text Table 8 presents data for Mona Island, Central San Francisco and Santa Rita on daily rainfall amounts equal to or greater than 0.10 inch and 0.50 inch. Mona has a higher frequence of light rains than the south coast stations. Again the seasonal variation is less marked at Mona. These data reflect the higher incidence of lighter daytime convective showers falling over the island. However, the frequency of heavier rain showers is about the same at all stations.

Text Table 8
Mean Number of Days With Rainfall Equal to or Greater than 0.10 Inch.

	JAN	*FEB*	*MAR*	*APR*	*MAY*	*JUN*	*JUL*	*AUG*	*SEP*	*OCT*	*NOV*	*DEC*	*ANN*
Mona Island	5	3	4	5	7	6	6	6	6	5	5	6	64
Central San Francisco	2	1	2	4	4	5	3	6	7	7	5	3	49
Santa Rita	2	2	1	6	4	5	4	5	7	6	4	3	49

Text Table 8 (Contd.)

Mean Number of Days with Rainfall Equal to or Greater than 0.50 Inch

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Mona Island	2	1	1	2	3	2	3	3	2	2	2	2	25
Central San Francisco	1	1	1	2	2	3	2	3	4	3	2	1	25
Santa Rita	1	1	1	3	3	2	2	3	4	4	2	1	27

THE TEMPERATURE REGIME

Lack of temperature data for Mona prevents a thorough analysis of this important climatological element. However, some general conclusions can be drawn. The size of the island would result in a maritime temperature regime with little or no land mass influence. As a base line, the mean monthly and annual temperatures for La Romana on the extreme southeast coast of Dominican Republic, Vieques Island and the Puerto Rico south coast are offered on Text Table 9.

Text Table 9
Mean Monthly and Annual Temperature F°

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANN.
La Romana, Dominican Republic												
74.8	75.4	76.3	78.3	79.7	80.9	81.1	81.9	80.9	80.4	78.6	76.5	78.7
Vieques Island												
76.7	77.0	77.3	78.6	80.6	81.7	82.2	82.6	82.0	81.4	80.0	77.9	79.8
Puerto Rico South Coast												
76.1	75.9	76.7	78.2	79.7	80.9	81.6	81.6	81.4	80.8	79.5	77.7	79.2

The lower winter month temperatures in the eastern end of Dominican Republic are probably somewhat more representative for Mona since its further westerly position would allow it to lie somewhat deeper in any cold air push from the north during these months. On the other hand, the sea surrounding Mona would have a tempering effect and the difference with the Puerto Rico south coast would probably not exceed one degree on a long term basis. The diurnal temperature range would of course exceed the seasonal and monthly range. Based on the Vieques data, the mean daily maximum and minimum temperature for each month of the year and annual means are shown in Text Table 10 as an indication of the probable diurnal range at Mona.

Text Table 10
Mean Diurnal Temperature Range - Mona Island (Estimated)

JAN.	*FEB.*	*MAR.*	*APR.*	*MAY*	*JUNE*	*JULY*	*AUG.*	*SEP.*	*OCT.*	*NOV.*	*DEC.*	*ANN.*
Mean Daily Maximum												
84.4	84.7	85.7	86.6	87.8	88.9	89.6	90.2	89.2	88.8	87.5	85.6	87.4
Mean Daily Minimum												
68.9	69.3	68.9	70.5	73.3	74.5	74.8	75.0	74.7	73.9	72.4	70.2	72.2
Daily Range												
15.5	15.4	16.8	16.1	14.5	14.4	14.8	15.2	15.5	14.9	15.1	15.4	15.2

TROPICAL CYCLONES:

The lack of complete observational data including wind speed and direction preclude a detailed analysis of the history of tropical cyclones affecting Mona Island. However, a study of storm tracks and associated rainfall amounts at Mona for the period 1871 thru 1971 permits a reasonable estimate of those tropical cyclones affecting the island during this past century. The criteria applied to identify a particular storm as having significantly affected Mona was a rainfall accumulation of at least 2.00 inches during the storm passage. In addition those known fully developed hurricanes which passed within 60 nautical miles of the island were included[5]. There are a total of 20 tropical cyclones listed for the one hundred years of record studied. Of this total, there are 6 fully developed hurricanes which, on the basis of available data, appear to have passed over Mona. These are listed in Text Table 11. This hurricane count compares to a total of 7 hurricanes which have crossed Puerto Rico for the same period.

Text Table 11
Hurricanes over Mona (1871 - 1971)

Date	*Name*
September 13, 1876	San Felipe I
September 1, 1896	San Román
August 8, 1899	San Ciriaco
August 22, 1916	San Hipólito II
July 23, 1926	San Liborio
September 11, 1931	San Nicolás

THE WIND REGIME

The characteristics of the surface wind pattern at Mona are of potential interest to the planner and would of course significantly influence any structural design planned for the island. Although no wind data are available for Mona itself, there are some general conclusions which can be drawn based on other stations in the Caribbean area which, like Mona, have a relatively free exposure to the easterly trades. The wind observations at the east end of Puerto Rico at the Roosevelt Roads Navy Base closely approximate this requirement. The slight percentage of time when the Puerto Rico land mass to the west of Roosevelt Roads might influence the free trade flow at Roosevelt Roads can be neglected for the purpose of this discussion. This influence would bias the representation of the Mona surface wind as follows:

1. Sea breeze augmentation of the normal easterly trade flow (on shore). This would result in slightly higher daytime wind speeds than at Mona.
2. Down slope drainage from the Luquillo mountains to the west of Roosevelt Roads resulting in some increase in either frequency of low velocity night winds from the northwest or of calms.

With the above two reservations in mind, the annual wind rose distribution of wind direction by speed groups for Roosevelt Roads, Puerto Rico is presented in Appendix Table 1 as a general guide to planning in Mona where the wind parameter is a significant weather factor. Text Table 12 presents the overall per cent frequency of direction by 16 compass points and the associated mean wind speeds.

Text Table 12
Per cent Frequency of Wind Direction and Speed

Direction	Per cent	Mean Wind Speed
N	2.4	7.8
NNE	2.7	10.2
NE	10.2	10.5
ENE	17.0	9.7
E	27.0	8.6
ESE	12.1	9.2
SE	6.4	8.2
SSE	2.5	7.8
S	3.7	8.4
SSW	1.3	8.6
SW	1.5	6.9
WSW	.8	5.0
W	.7	5.0
WNW	.3	4.8
NW	1.0	5.6
NNW	1.3	6.0
CALM	9.0	---

Extreme wind speed data for use in determining design wind pressure and loads is a risky statistic to extrapolate and is not attempted here. Wind speeds associated with tropical cyclones moving across Mona are for the most part in a buildup stage after having lost some velocity due to the frictional effect of the Puerto Rico land mass. Maximum wind speeds of 85 mph were estimated by Coast Guard personnel during Hurricane Beulah of 1967 and this same storm moved into Santo Domingo a few hours later with measured speeds of 140 mph. The extreme wind distribution analysis for San Juan wind data indicate a frequency of about 40 years for an 85 mph wind, 71 years for 100 mph wind and about 269 years for 150 mph faster mile winds. Gust velocities of 78 mph, 104 mph and 156 mph have return periods of about 8 years, 32 years and 130 years respectively. It is reasonable to assume that Mona's extreme winds would not vary from this frequency by a significant factor.

SUMMARY

Although lying deep in the tropical maritime belt of the easterly trade winds, the climatic classification of Mona Island is Semi-arid. The average annual rainfall of 31.85 inches does not meet the water needs of growing vegetation and the year round moisture stress results in 30.02 inches of water deficiency. Rainfall analyses were based on the standard 30 year record ending in the last decade as a world wide standard data base set by the World Meteorological Organization for determining climatological normals. The lack of large tropical storms and hurricanes affecting the island during this period of record results in a somewhat lower mean annual rainfall than cited in previous studies. However, this should not be considered as an indication of significant climatic change towards a drier regime. The rainfall, temperature and resulting vegetative growth are similar to the south coast of Puerto Rico around the Guánica area. The relatively dry and wet seasons are less marked than in the Guánica area and there is an indication that much more of the rainfall occurs in the form of lighter convective showers than in Puerto Rico. Extremes of temperature are tempered by the surrounding ocean although the island is more subject to cooler air outbreaks during the winter months compared to Puerto Rico. Tropical cyclones affect the island on the average of about once every five years and fully developed hurricanes pass over the island about once every 17 years. Extreme wind speeds of hurricane force (74 mph) or higher can be expected to affect the island about once very 8 years. There is no land breeze —sea breeze pattern imposed over the easterly trade winds because of the small land mass. The general pattern of the surface winds is one of the undisturbed easterly trade winds with a component from the east blowing about 80 per cent of the time on an annual basis.

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APPENDIX TABLE I

PERCENTAGE FREQUENCY OF WIND DIRECTION AND SPEED (FROM HOURLY OBSERVATIONS)

Station: 11630 NS Roosevelt Roads, Puerto Rico 49-50.57-67

ALL WEATHER

Speed Knts. Dir.	1 - 3	4 - 6	7 - 10	11 - 16	17 - 21	22 - 27	28 - 33	34 - 40	41 - 47	48 - 55	≥56	Per cent	Mean Wind Speed
N	.2	.8	.9	.4	.1	.0						2.4	7.8
NNE	.1	.4	1.0	1.0	.2	.0						2.7	10.2
NE	.2	1.6	4.0	3.5	.8	.1	.0					10.2	10.5
ENE	.6	3.6	6.7	5.2	.8	.1	.0					17.0	9.7
E	1.7	6.9	11.9	5.9	.6	.0						27.0	8.6
ESE	.5	2.3	5.6	3.4	.2	.0	.0					12.1	9.2
SE	.5	1.8	2.8	1.4	.1	.0						6.4	8.2
SSE	.3	.7	1.0	.4	.0	.0						2.5	7.8
S	.2	1.0	1.7	.7	.0	.0	.0					3.7	8.4
SSW	.1	.3	.5	.3	.0			.0				1.3	8.6
SW	.3	.6	.5	.2	.0	.0						1.5	6.9
WSW	.3	.3	.1	.0	.0	.0						.8	5.0
W	.2	.3	.1	.0	.0							.7	5.0
WNW	.1	.1	.1	.0								.3	4.8
NW	.3	.4	.3	.1	.0							1.0	5.6
NNW	.3	.5	.4	.1	.0							1.3	6.0
CALM												9.0	
	5.8	21.7	37.7	22.6	2.8	.3	.0	.0				100.0	8.1

Total Number of observations, 04055

Apéndice: B

Geology and Mineral Resources of Isla de Mona, P.R.

By

John M. Aaron
U.S. Geological Survey
San Juan, Puerto Rico

Publication authorized by the Director, U. S. Geological Survey.

INTRODUCTION

Isla de Mona is a carbonate island characterized by a very flat, gently sloping upland surface that is terminated by high, sheer sea cliffs along its northern and southern perimeter and by somewhat lower, less steep cliffs that descend to coastal lowlands along its western, southwestern, and southeastern margin.

Geologically, the island is composed almost entirely of limestone and dolomite that vary widely in texture, age, and origin. The sea cliffs and escarpments around the periphery of the island contain numerous caves whose distribution is chiefly limited to certain well-defined zones within the carbonate rocks. Typically, the caves contain deposits of phosphorite, a granular material derived from bat guano and composed largely of the mineral apatite, a calcium phosphate. The phosphorite, used principally for fertilizer, is the only rock or mineral resource of Isla de Mona that has been commercially exploited. The phosphorite deposits are no longer economic because market conditions and competition from much larger and more easily mined phosphate deposits would not justify the difficulty and expense of mining the relatively small tonnage of phosphorite still present in the caves.

Potential mineral resources include limestone and dolomite. It is highly doubtful, however, that these deposits could be developed economically under present market conditions.

The following description of the geology and mineral resources of Isla de Mona is based largely on published reports (Kaye, 1959; Wadsworth, 1954) and an extensive geologic survey of the island carried out in the summer of 1964 by Reginald P. Briggs and V.M. Seiders (in press), both geologists of the United States Geological Survey. The geologic information contained herein is drawn from notes by Briggs, and from a geologic map by Briggs and Seiders (in press).

GEOLOGY

Isla de Mona is composed almost entirely of carbonate rocks —stratified limestone and dolomite, reef rock, and boulder rubble— that range in age from lower or middle Mocene (about 18-25 million years old) to Holocene (Recent). The bulk of the island is composed of two generally flat-lying rock units, the Isla de Mona Dolomite and the Lirio Limestone.

Isla de Mona Dolomite

The Isla de Mona Dolomite is exposed in the sheer cliffs that extend from the vicinity of Punta Este northward and then westward to Punta el Capitán (Fig. 1), and it crops out sporadically at the base of the cliffs that extend from a point northwest of Playa del Uvero southeastward to Punta Caigo o no Caigo and eastward to Punta Los Ingleses. It also crops out in Bajura de los Cerezos, a northwest-trending linear lowland in the center of the island.

The Isla de Mona Dolomite is a very pale orange to moderate —orange-pink, thick— to very thick bedded, finely crystalline, sparsely fossiliferous calcareous dolomite. The total thickness of the unit is unknown because the base is below sea level.

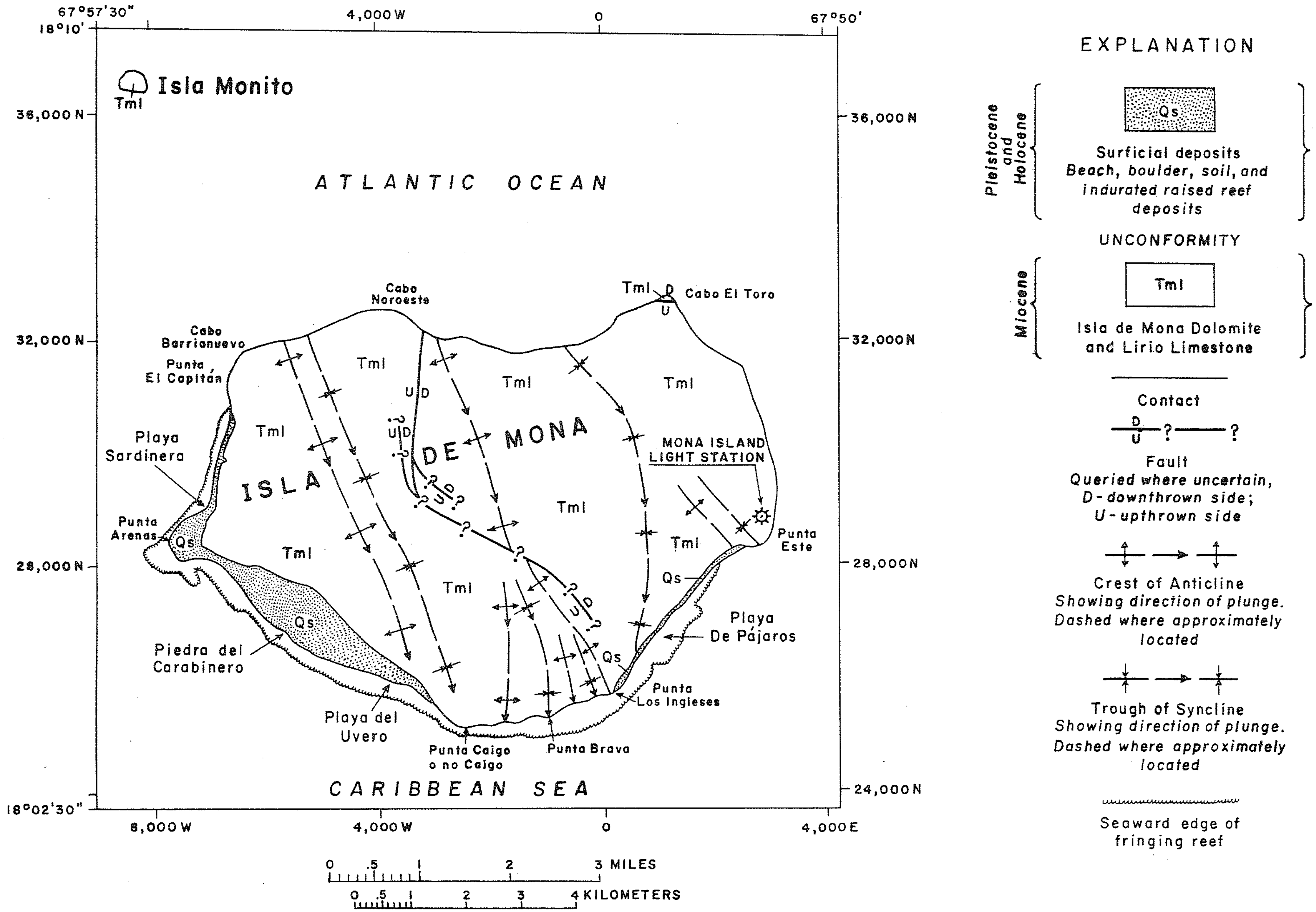

Figure 1. —Generalized geologic map of Isla de Mona quadrangle, Puerto Rico (modified from Briggs and Seiders, in press).

A thickness of slightly more than 80 m is exposed above sea level. Chemical analyses show that the chemical composition averages about 18 weight per cent MgO (38 per cent $MgCO_3$) and about 34 weight per cent CaO (60 per cent $CaCO_3$), and, on the whole, does not vary widely. This average composition represents about 8 per cent excess $CaCO_3$ over the amount that would be contained in $CaMg(CO_3)_2$, the mineral dolomite. The noncarbonate fraction of the analyzed dolomites ranges from 0.5 to 5.0 per cent and averages about 2 per cent. In terms of rock purity these figures, along with the 8 per cent average excess calcite, place the Isla de Mona Dolomite well within the range of what would be considered pure dolomite for most industrial purposes.

The Isla de Mona Dolomite is early or middle Miocene in age. The age determination is based on four species of planktonic foraminifera (E.A. Pessagno, written commun., 1970). More than a dozen other fossil species, all pelecypods and gastropods, have been found but they are similar to modern types and provide no basis for age determination.

Lirio Limestone

The Lirio Limestone overlies the Isla de Mona Dolomite with a gradational contact. It underlies most of the upland surface of the island, forms most of the cliffs on the south side of the island, and crops out at the top of most of the northern cliffs. It is a pale-orange to grayish-orange-pink, hard, fine-grained, moderately fossiliferous limestone. Bedding thickness ranges from 2 to 3 m, but locally is more than 5 m. The maximum exposed thickness of the Lirio is about 40 m. Because the top of the Lirio is not exposed it is not known how much thicker the unit may once have been.

Chemically, the Lirio Limestone averages about 54 per cent CaO (96.5 per cent $CaCO_3$) and about 1 per cent MgO (2.1 per cent $MgCO_3$), with less than 1 per cent noncarbonate material. The available analyses vary little. By any generally accepted standard, the Lirio is a pure limestone, and in some cases it would rank as a high-calcium limestone, a valuable rock in much industrial demand because it is almost pure (95 per cent or more) calcium carbonate.

The Lirio Limestone is Miocene in age, and could not be older than early or middle Miocene, the apparent age of the underlying Isla de Mona Dolomite.

Lateritic Clay Soil

Lateritic soil composed almost entirely of dark reddish-brown clay, in patches as much as 400 m long, mantles about 5 per cent of the upland surface of Isla de Mona. The age of the soil is limited by the age of the Lirio Limestone on which it has formed, thus the soil could be as old as Miocene and as young as Holocene.

Reef Flat Limestone

Segments of raised reef flat, 2 to 10 m above sea level, lie along the shore from Punta Este southward around the island to Punta El Capitán (Fig. 1). The reef deposit is a grayish-orange-ink limestone that consists mostly of fossils and fossil frag-

ments, primarily pelecypods and gastropods. Reef corals in growth position are common. The thickness of the reef limestone ranges from 3 to perhaps 10 m, and it rests unconformably on both the Lirio Limestone and the Isla de Mona Dolomite. The fossil content indicates that the reef limestone deposits are Pleistocene.

Limestone Boulder Deposits

Boulder deposits with minor sand and gravel lie along the base of the cliffs from Punta Este southward and westward to Punta El Capitán. The boulders are derived chiefly from the Lirio Limestone, which forms the adjacent cliffs. The deposits contain boulders as much as 50 m in diameter (Kaye, 1959). The relationship of the boulder deposits to sea-level nips and to the raised reef flats indicates that the boulder deposits probably range in age from Pleistocene to Holocene.

Phosphatic and Calcareous Cave Deposits

The caves around the periphery of the island contain deposits of phosphorite and reprecipitated calcite. The phosphorite is a moderately to well stratified yellowish-brown to dark-yellowish orange and pale-reddish brown granular material derived diagenetically from bat guano (Kaye, 1959). The principal mineral constituent is hydroxylapatite, a calcium phosphate. other less important phosphate minerals include crandallite, brushite, and martinite (Altschuler, 1959). Phosphorite covers about 25 per cent of the floor area of most caves, and, in undisturbed areas, ranges in thickness from about 20 cm to about 2 m. In mined-out areas the phosphorite apparently was as much as 3.5 m thick.

Other cave deposits include calcareous dripstone and flowstone in the form of columns, stalactites, stalagmites, and curtains, and rock rubble on the cave floors.

The age of the cave deposits is, of course, limited by the age of the caves themselves. The cave deposits must be younger, but by how much is conjectural. There are too few bats in the caves today to supply raw material for the phosphorite, so some sort of an evironmental change, perhaps disease or predators, a climatic change, or perhaps even the presence of mining activity, is likely to have occurred. A climatic change is also suggested by the massive flowstone and dripstone features which seem not to be related to the scant rainfall of today (Kaye, 1959). The age of the cave deposits thus is rather uncertain —certainly younger than the Lirio Limestone (Miocene) but probably not strictly modern.

Meach Deposits

Beach sands and beach rock (calcium carbonate —cemented beach sand) are present locally on Isla de Mona. The largest sandy areas extend from Playa Sardinera southeastward to Playa del Uvero (Fig. 1), and from Punta los Ingleses northeastward to Playa de Pájaros, and slightly beyond. The beach deposits are composed of fine to medium-grained grayish-pink calcite and aragonite sand, chiefly comminuted shell debris.

Beach rock forms thin layers approximately parallel to the present beaches, and is exposed in beaches from Playa del Uvero to Punta Arenas and Playa Sardinera. The beach deposits are Holocene.

Geologic Structure

Isla de Mona is structurally rather simple. The Isla de Mona Dolomite and Lirio Limestone are folded into broad, shallow anticlines and synclines that plunge gently southward or southeasterly (Fig. 1).

Only two faults are known on the island. The principal fault is well exposed in the sea cliff about 800 m east of Cabo Noroeste, where the western side of the island is displaced about 10 m upward relative to the eastern side, and the Lirio Limestone has been eroded from the upthrown western block. The other fault occurs at Cabo El Toro (Fig. 1), where less than 1 m of displacement, down to the north, occurs on an essentially vertical fault plane. This fault may represent slip along a joint plane. The age of the faulting is not known, but it must be no older than early or middle Miocene, the age of the rocks displaced, and it may be considerably younger. There is no evidence that the faulting is very recent, however, in spite of the modern seismic activity of the Mona Passage.

Vertical joints occur in the bedrock of Isla de Mona, and commonly are oriented parallel to the cliffs. Percolation of meteoric water through such joints contributed to cave development and karst features on the upland surface and to the development of phosphorite from bat guano.

PHYSIOGRAPHY

Upland Surface

The upland surface ranges in elevation from more than 90 m near Cabo Noroeste to about 30 m near Playa de Pájaros. The maximum local relief is about 40 m.

The upland surface is very gently undulating and slopes less than 1^{o} generally southward. Despite the apparent overall flatness of the upland, the ground surface is extremely rough. The roughness is due to ubiquitous irregularities, such as small inkholes, solution cavities, cracks, zanjones, and ridges that result from solution of the limestone bedrock. It is, in essence, a karst surface with a local relief of less than 1 m.

The upland is bounded almost completely by steep to vertical escarpments that locally are overhanging. The escarpments drop to the sea except where the upland is bounded by narrow coastal lowlands along the western, southwestern, and southeastern sides of the island. The forms of the escarpments appear to be lithologically controlled. Generally, the straighter, higher (60 m or more), sheer sea cliffs are associated with the more resistant Isla de Mona Dolomite, whereas the lower, less steep, more irregular escarpment between the upland surface and the coastal lowland is associated with the relatively less resistant Lirio Limestone. The high, steep cliffs exposing the Isla de Mona Dolomite appear to be stable, as there is a well-defined, deeply incised nip at the base of the cliffs at the sea water interface. The nip is a solution feature that undercuts the cliff; thus its survival is a function of the relative balance between the rate of solution and the rate of cliff recession by erosion.

Coastal Lowland

The upland is bordered by a coastal lowland around the sothern edge of the island, from Punta Este to Punta Los Ingleses, and from just west of Punta Caigo no

Caigo almost to Punta El Capitán on the west side of the island (Fig. 1). The coastal lowland is underlain by reef flat, beach sands, and boulder deposits (Fig. 1), and it ranges in elevation from sea level to about 10 m at the base of the upland cliffs.

Caves

Caves are numerous and conspicuous features in the cliffs that form the periphery of the upland surface, and, in terms of area, they underlie about 1 to 2 per cent of the upland. Most commonly caves are located in the lower 10 m of the Lirio Limestone. Caves in the Ilsa de Mona Dolomite, typically smaller and less common than in the overlying Lirio Limestone, are apparently localized in two stratigraphic zones at about 15 m and 50 m below the contact with the Lirio.

Surveys by Briggs and Seiders (in press) of all known major cave systems in the lower 10 m interval of the Lirio Limestone show that these systems terminate inward from the cave mouths. Termination is not limited simply to gradual narrowing of passages or to lowering of the ceilings. Commonly the caves end abruptly in solid rock walls. Briggs and Seiders (in press) found that average cave penetration from the cliff face is on the order of 50 m, that the deepest cave surveyed penetrates 240 m (airline), and that there is no evidence to support the popular notion that it is possible to traverse the island underground from one side to the other through connected cave systems.

Most caves are subdivided, festooned, and columned by deposits of reprecipitated calcite in the form of flowstone and, locally, stalagmites and stalactites. Such features are less common in the more inland parts of the caves.

Caves with roofs near the upland surface typically have openings to the surface. The openings of such caves have the form of irregular truncated cones that rise from the cave floor as much as 10 m, narrowing from a diameter of 10 to 60 m at the cave floor to a diameter of a few centimeters to as much as 40 m at the surface. The floors of such sink caves contain a rubble heap resulting from roof collapse.

All of the known caves contain deposits of phosphorite produced by alteration of bat guano by percolating meteoric water.

ECONOMIC GEOLOGY

Phosphorite

Cave phosphorite, a granular material composed largely of calcium phosphate and used as fetilizer, is the only mineral resource of Isla de Mona that has been commercially exploited. Recent studies by F.H. Wadsworth (personal comm., 1972) have greatly clarified the early history of discovery and exploitation, which formerly were poorly known. Prospecting occured at least as early as 1848 and probably earlier. Sustained mining operations by different companies took place from 1877-1889, 1890-1896, and from 1905-1924. Shipment records from the period indicate that a total of 144,000 metric tons (mT) were shipped during the 19th century operations. Shipment records and records of royalty payments for the period 1910-1920 suggest that the maximum tonnage produced during this period was 25,000 mT, (F.H.

Wadsworth, personal comm., 1972). Thus, the total amount of phosphorite extracted from Isla de Mona ranges from about 147,000 to 172,000 mT.

Estimates of the original and present phosphorite reserves vary wildly. An early survey estimated 21,700 mT present. Exploration in 1901 indicated reserves of about 460,000 mT, of which as much as 25,000 mT were later mined (F.H Wadsworth, personal comm., 1972). One estimate of present reserves ranges as high as 910,000 mT.

The 1964 survey by R.P. Briggs and V.M. Seiders indicated that from 168,500 mT to 250,000 mT of phosphorite were originally present in the known caves, of which about 148,000 mT were mined. They estimate that about 13,500 mT of minable phosphorite remain in the 12 accessible caves that they surveyed. The total reserves for all the known caves may range as high as 102,000 mT, but, because mining is known to have been very widespread, it is unlikely that more than 50,000 mT of phosphorite remain on Isla de Mona. A similar estimate of reserves was made in 1964 by representatives of a mining company.

In view of the very limited phosphorite reserves on Isla de Mona, the relative difficulty and expense of mining the remaining deposits there, and the competition from more accessible, easily mined phosphate rock in Florida, central Tennessee, contiguous parts of Idaho, Montana, Utah, and Wyoming, and smaller deposits in numerous other areas, it is inconceivable that the Mona phosphorites could be of further economic interest.

Limestone

The Lirio Limestone is quite pure calcium carbonate, $CaCO_3$, of the sort that normally would be considered a valuable source of lime, a basic chemical of prime importance having manifold industrial applications. Possible applications include use as agricultural lime, a soil conditioner used to correct soil acidity, as a fluxing agent in the smelting and refining of metals, and as a chemical raw material used in the manufacture of Portland cement, glass, and many other products.

The Lirio could be quarried for any of the above uses. The unit is rather thin, however, averaging only about 10 m in thickness, and quarry operations probably would have to be limited to the thicker parts of the formation near Playa de Pájaros and near Playa Sardinera. Nevertheless, reserves are adequate for operations lasting many years. Despite the purity of the Lirio Limestone, however, limestones of similar purity are available in Puerto Rico in greater abundance, with better accessibility and transportation facilities, and closer to potential industrial consumers. Therefore, it is not likely that the Lirio Limestone of Isla de Mona could be considered a viable economic resource in the near future.

Dolomite

The Isla de Mona Dolomite is in much the same potential market condition as is the Lirio Limestone. The dolomite rock is relatively pure mineral dolomite, $CaMg(CO_3)_2$, for which there is widespread demand. It has some uses in common with limestone crushed stone, concrete aggregate, road metal, manufactured sand, poultry

grit, sewage filter beds, and the like. Dolomite is also of independent value as, among other things, refractory and insulation material.

The Isla de Mona Dolomite underlies the entire island and the potential tonnage is great. Exploitation by quarrying would be hindered by the presence of the overlying Lirio Limestone, which would require extensive and expensive stripping or recourse to underground mining. Dolomites of comparable purity, though more limited in extent, are available in Puerto Rico. Thus, like the Lirio Limestone, the Isla de Mona Dolomite is unlikely to be a real economic resource in the near future, if ever. Dolomite is commonly and readily available in too many other places.

Oil and Gas

Although the folds and faults of Isla de Mona theoretically might create favorable sites for oil and natural gas, no evidence of oil and gas has been reported from the general area, and no local rock units are known that might be source rocks.

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Apendice: C

Soils of Mona Island

By

Luis H. Rivera, Soil Scientist
USDA-Soil Conservation Service

MAPPING UNITS IN MONA ISLAND

Symbol	Name	Acreage
Ch	Coastal beach	44
Jd	Jaucas sand	157
Lo	Limestone outcrop	13755
ScB	San Germán cobbly sandy loam	260
	Total	14216

COASTAL BEACH

Coastal beach (Ch) consists of narrow strips of light colored pinkish white beach sands along the coast. It occupies nearly level sand ridges and dunes caused by action of waves on marine sands. The depth to salt water is variable. The sands, which are calcareous, contain numerous seashells, corals, and shell fragments throughout. No volcanic fragments were found.

Most areas lack vegetation, but in some areas there are scattered coconut palms. The most common vegetation consists of common seagrapes (uva playera), and beach morning glory, (bejuco de playa). Some areas are covered with logs, leaves, and seaweeds deposited by the waves. (Capability Units VIIs-1)

JAUCAS SAND

The Jaucas series consists of deep, excessively drained soils that are calcareous and rapidly permeable. These soils occupy hummocky areas, above high tide, along the coast. They formed in marine deposits of sand-sized material derived from coral and seashells. The climate is semiarid. Rainfall amounts of 20 to 30 inches, and the annual temperature ranges from 78^{o} to 81^{o}F. Included in mapping were small spots of coastal beach.

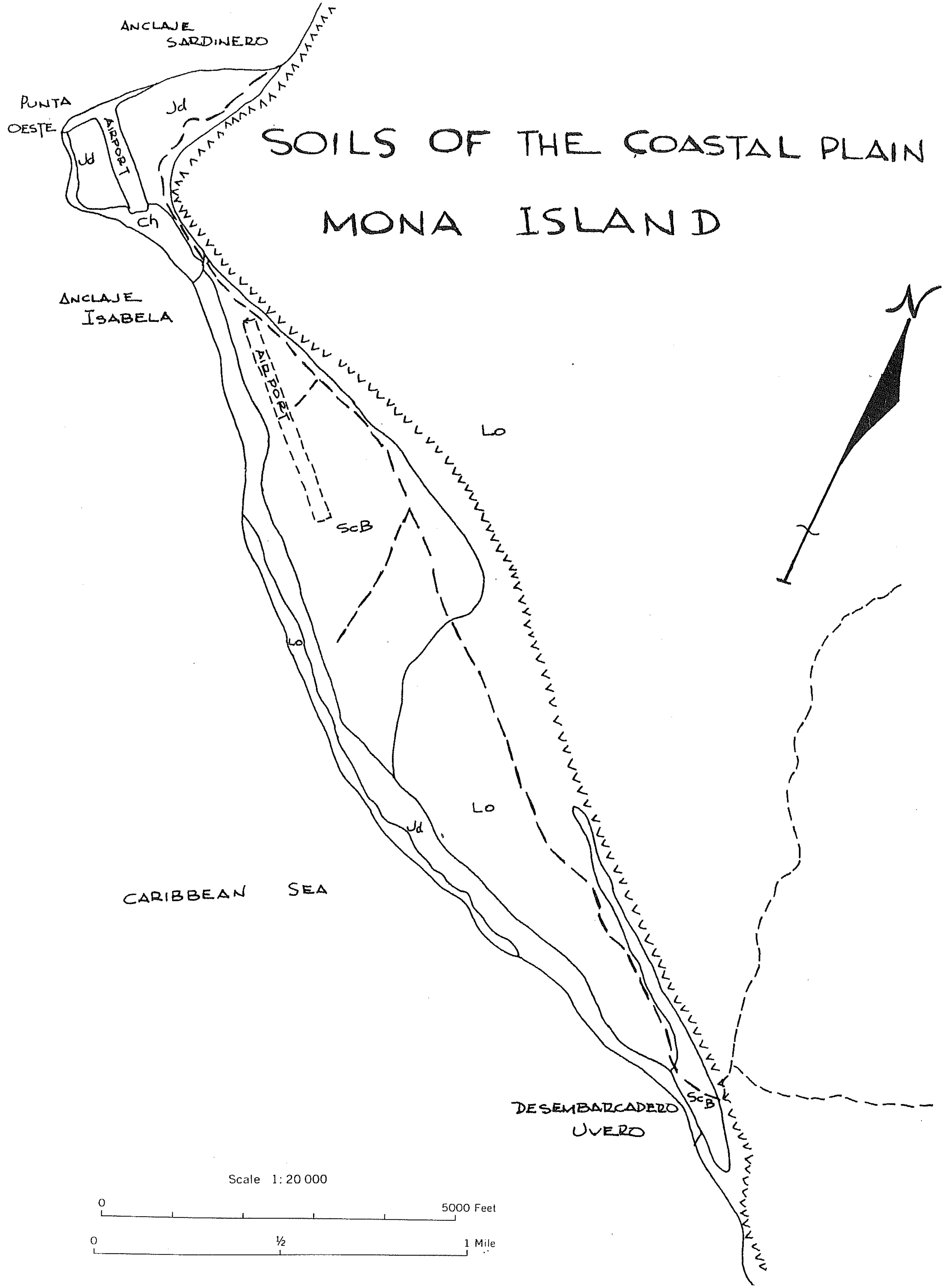
In a representative profile the surface layer is dark-grayish brown, calcareous sand about 11 inches thick. The upper part of the substratum, to a depth of about 17 inches, is very pale brown, calcareous, loose sand. The lower part is pinkish white, calcareous, loose sand more than 60 inches thick.

Representative profile of Jaucas on Mona Island 150 meters, south of police headquarters, 50 meters from Pozo del Portugüez:

A_1 —0 to 11 inches, dark grayish brown (10YR 4/2) sand (shell fragments); single grains; loose; many fine and medium roots; strong effervescence; clear, abrupt boundary.

C_1 —11 to 17 inches, very pale brown (10YR 7/3) sand (shell fragments); single grain; loose; few fine roots; strong effervescence; clear, wavy boundary.

SOILS OF THE ÇOASTAL PLAIN MONA ISLAND



C_2 —17 to 60 inches ;+pinkish white (7. 5YR 8/2) sand (shell fragments); single grains; loose; strongly calcareous.

This soil is nearly level. It is close to the beach at elevations above high tide. Permeability is rapid, the available water capacity is very low, and fertility is very low.

This soil is not suitable for cultivation. Its use is restricted mainly to grazing and wildlife habitat. This soil is in coconuts and an undergrowth of native pasture, low brush, and some scattered Australian pine trees. Improvement of pasture or range by such practices as fertilizing, seeding and controlling water are not practical because of the available water capacity, the permeability, the fertility and the low rainfall. (Capability Unit VIIs-2)

LIMESTONE OUTCROP

Limestone Outcrop (Lo) is in areas where hard, massive, gray and pinkish gray limestone crops out on 90 to 100 per cent of the surface. It has many hones and knife-like edges. In areas not entirely covered by limestone, there are irregularly shaped patches of gravelly soil material that has varying colors. Loose gragments of limestone of varying sizes and shapes are common. Included in mapping are small depressions in which there is soil material of variable texture, color, and thickness.

The use of this land type is restricted to wildlife habitat or water supply. The limitations to the use of this land type for other purposes are very severe. In most areas the vegetation consists of brushy forest or brushy pasture that has little agricultural value, but in semiarid areas it is chiefly in cactus and low brush.

Some limestone rocks are found with a cemented red soil material. Patches of red soil are found in areas of Los Cerezos, in the west-central part, in Cuevas del Centro and in Las Caobas, in the north-western corner. The largest patch of these red soils, 3 to 4 acres, is found in Los Cerezos. The following description is representative of these red soils:

0 to 3 inches, dusky red (2.5YR 3/3), silt loam, no apparent aggregation; loose, nonsticky, nonplastic; many fine and medium rots; pH 8.0; common small shell fragments; clear boundary.

3 to 10 inches, dark red (2.5YR 3/6) clay loam; weak fine subangular blocky structure, breaking to weak fine and medium granular; friable, slightly sticky, slightly plastic; few fine roots; pH 7.0; clear smooth boundary.

10 to 26 inches, dark red (10R 3/6) clay; weak fine and medium subangular blocky structure; firm, slightly sticky, plastic; few fine pores; few fine roots; pH 6.5.

26 inches ±, hard limestone.

Three additional holes were made with the auger looking for average depth to limestone rock, and it was found at 30 inches, 20 inches and 24 inches. Few outcrops of limestone rock are on the surface. Because this soils is in small areas, and sparsely distributed, we decided not to separate it on the map. (Land capability of the Limestone outcrop unit is VIIIs-2)

SAN GERMAN COBBLY SAND LOAM

The San Germán series consists of very shallow, well drained soils that are calcareous and have moderately rapid permeability. These soils formed in residual material weathered from hard limestone. The surface layer contains gravel or cobblestones. The slope ranges from 0 to 5 per cent. The climate is semiarid. Rainfall amounts to 20 to 30 inches, and the annual temperature ranges from 76° to 81°F.

In a representative profile the first layer is dark brown, calcareous, cobbly sandy loam about 6 inches thick. The next 8 inches are made up of light yeloowish brown, soft limestone that is mixed with cobbles of hard limestone. This layer rests abruptly on hard limestone that cannot be penetrated with a spade.

These soils are used for grazing because of the shallowness to rock and the slopes. Some areas are in brush.

The following description was written 50 meters west of the airport, and is representative of the series in the Mona Island:

Ap —0 to 6 inches, dark brown (10YR 3/3) cobbly sandy loam; weak fine granular structure; friable, nonsticky, and nonplastic; many fine roots; strong effervescence; clear abrupt boundary.

C —6 to 14 inches, light yellowish brown (10YR 6/4) soft limestone mixed with cobbles of hard limestone.

R —14 inches; hard limestone.

San Germán cobbly sandy loam occurs on gentle slopes on Mona Island, between the limestone escarpment and the sea. It is very shallow to bedrock. It has a profile similar to that described as representative of the series. Cobblestones cover more than 40 per cent of the surface. This soil has been influenced by the nearby sands of the coast.

Included in mapping are areas of Limestone outcrop and some spots of soils that have a sandy surface layer and that is also underlaid by hard limestone. Also included were spots of soils that have a thin substratum, only 3 to 4 inches thick, that is underlain by hard limestone. These areas are not common and make up 10 per cent or less of the acreage.

This soil is not suitable for cultivation. Its use is restricted mainly to pasture, and most of the acreage is in native pasture and low brush. Shallowness to bedrock is a severe limitation that cannot be corrected. (Capability Unit VIs-21)

MANGROVE SWAMP

There is a very small patch of this land type, about 1 acre in size. It does not have agricultural value, but serves as habitat for birds and crabs. This area is under brackish water and is covered by a thick growth of mangrove trees.

TOPOGRAPHY

Except for the strip along the coast from Uvero Beach on the south coast, to Sardinera Beach on the west, Mona Island is a plateau and its topography is nearly plain. There are some smaller plateau within the big plateau, but slopes from one to the other never exceed 10 per cent. There is a rock escarpment around the island from Punta Caigo o no Caigo in the south, to a point near Sardinera Beach on the west. Height of the bed escarpment from sea level fructuates from 150 ft. to 200 ft. The area from Uvero to Sardinera is flat land. On approach from the air the island appears as a smooth table surrounded by high cliffs, which drop vertically to the sea over much of its perimeter. From Uvero west to near Punta Oeste a raised organic reef flat forms a broad flatland at a low elevation that is bordered to the north by cliffs. The general low flatland from Punta Oeste north to near Cabo Barrio Nuevo may be underlain by similar raised reef, but is chiefly composed of calcite sand. The remainder of the coast all around the north side of Mona is sheer cliff, apparently bordering on relatively deep water.

Apéndice: D

A Summary of Actual and Potential Water Resources Isla de Mona, P.R.

By

D.G. Jordan

Prepared by the United States Geological Survey
in cooperation with
Puerto Rico Environmental Quality Board
1973

[1] Publication authorized by the Director, U. S. Geological Survey

INTRODUCTION

The evaluation of water supply on Isla de Mona is an enigma. For many years after its discovery the island was shown in nautical charts as a watering port. It supported a fair size village of Taino Indians at a time when both food and water were plentiful.

Today the island is a barren scrub-covered waste. Available water supplies other than rainfall are meager and brackish. What has happened in the past 400 years to diminish the water resources of Isla de Mona may only be conjectured —climatic changes and changes in land use are possible causes.

The purpose of this report is to summarize information about the existing water resources of Isla de Mona and to theorize about potential water supplies for the island.

GEOLOGY

The geology of Isla de Mona was described by Kaye (1959) who assigned the name Lirio Limestone and Isla Mona Limestone to the two major rock types composing the island. R.P. Briggs and V.M. Seiders (197) after further study decided that the Isla Mona Limestone was predominately a dolomite and renamed the formation, the Isla de Mona Dolomite.

The Isla de Mona Dolomite is exposed in the sheer cliffs from Punta Este around the northern half of the island to Punta El Capitán (fig. 1) and it is exposed sporadically in the cliffs on the south half of the island. About 250 feet of the thick to very thick bedded finely crystalline dolomite is exposed above sea level. Some caves are visible in cliff faces, but they are generally small and poorly developed.

The Lirio Limestone, about 130 feet thick, overlies Isla de Mona Dolomite and covers most of the upland surface. It crops out at the top of the cliffs on the northern half and it forms most of the cliffs of the southern half of the island. Caves formed in the basal part of the Lirio Limestone are common features in the cliffs around the periphery of the island.

Small sinkholes and other solution features are well developed in the upland surface. Talus slopes at the foot of the cliffs between Punta Arenas and Punta Caigo o no Caigo overlie truncated Pleistocene and Holocene reef deposits that form a low flat shelf generally less than 15 feet above sea level and extending at its widest about two-thirds of a mile between cliff face and the sea (fig. 1). A thin deposit of calcareous sand covers the reef shelf from Playa Sardinera to Punta Arenas and the coastal fringe of the reef shelf from Punta Arenas to Playa de Uvero.

Isla de Mona is marked in a general north-south direction by a series of shallow anticlines and synclines and a fault system, as shown in figure 1. The fault system may be a zone of weakness along which solution processes have been more active than in the adjacent rocks. For example, one of the major surface depressions in the central part of the island seems to be in the area of the fault. Similarly, several depressions on the eastern part of the island seem to be associated with a syncline.

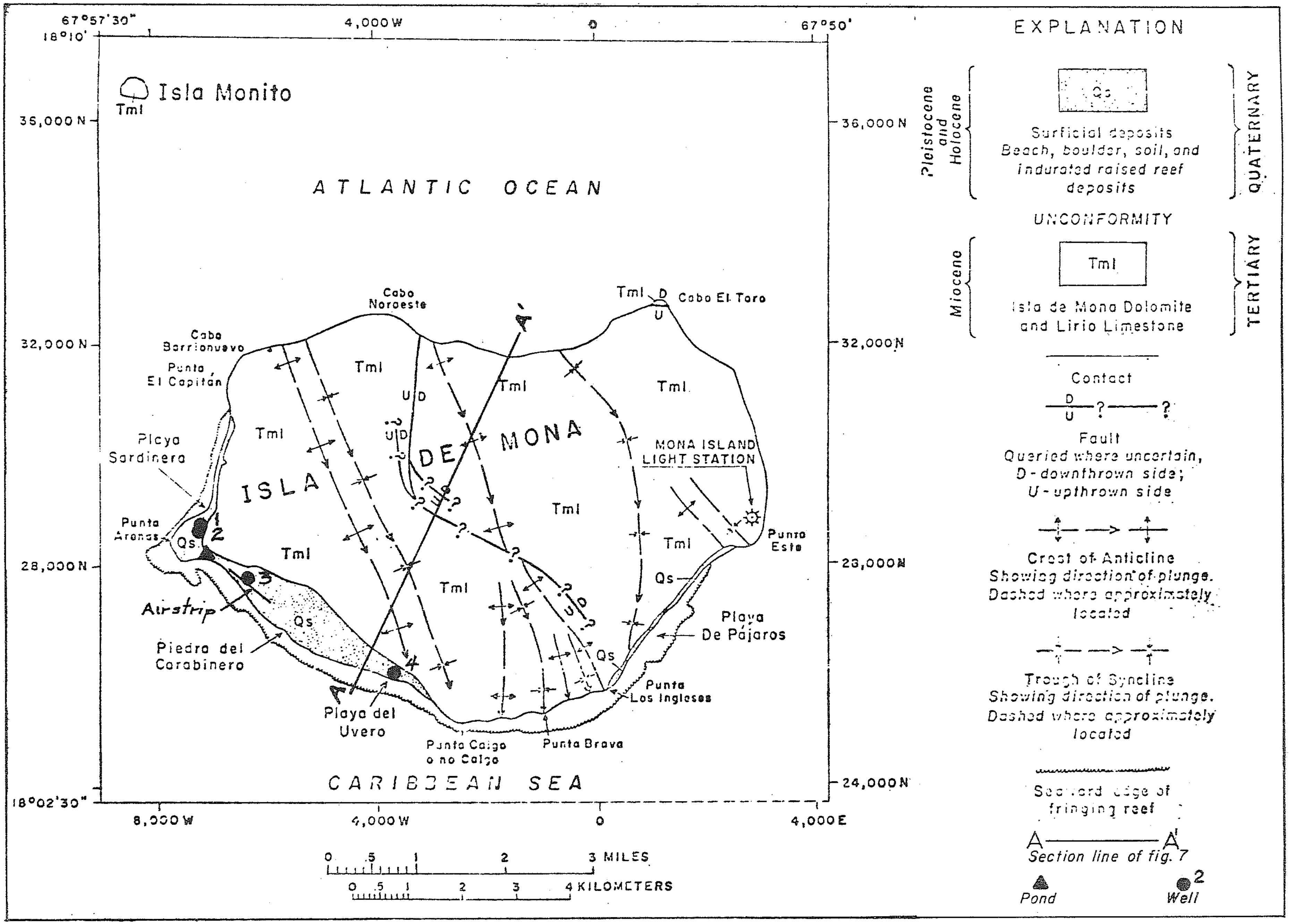


Figure 1.--Geology and location of wells and pond. (Geology after Briggs and Seidens, 197__, in press.)

RAINFALL AND EVAPOTRANSPIRATION

Annual rainfall at the lighthouse on the east end of Isla de Mona (fig. 2) averaged 32.5 inches from 1948-70, as shown in figure 2.

R.J. Calvesbert (oral commun., 1972) computed a 30-year normal rainfall of 31.85 inches. The least rainfall was 20.99 inches in 1962 and the greatest 52.11 inches in 1960. January through March is usually dry and seldom is rainfall more than 2 inches per month. Rainfall throughout the remainder of the year has a seasonal variation similar to that of Puerto Rico, with a rainy season August through November and a secondary rainy season in May. Major rainstorms, those exceeding 1 inch in 24 hours, occur on the average about 10 times a year. Rainstorms exceeding 2 inches in 24 hours are rare and occur an average of about twice a year. Major rainstorms occur most frequently in May and August through December.

Evaporacion and transpiration are the principal means by which water from rainfall is returned to the atmosphere. The process can be grouped under the general term of evapotranspiration or ET. ET probably consumes all rains of less than half an inch and the greater part of rains that are as much as 2 inches. Figure 3 shows the relation of ET to rainfall in Puerto Rico based on the relationship ET equal Rainfall minus Runoff (E.V. Giusti, written commun., 1971) primarily for mountain basins underlain by volcanic rocks. This relationship applied to Isla de Mona indicates an ET of about 30 inches would occur during a year of average rainfall (32 inches).

Because of the apparent high permeability of the Lirio Limestone and the general lack of soil to retain water, ET possibly is less owing to rapid infiltration. ET losses may be as low as 24 inches, based upon a review of major rainstorms from 1958 through 1970 and estimates of ET in conjunction with rapid infiltration. For the purpose of this report ET has been assumed to be 28 inches in a year of average rainfall.

EXISTING WATER RESOURCES

The existing known sources of water are meager —a brackishwater pond, a few dug wells, and a pool in a cave.

Surface Water

There are no streams on Isla de Mona or even dry channels that might carry intermittent flow following rainstorms. Depressions on the surface of the Lirio Limestone ranging from teacup-size to holes 5 feet in diameter and as much as a foot deep, are found throughout the island. These depressions can catch and hold rainwater for several days to several weeks.

A small brackish-water pond about 50 feet square and a foot or so deep lies at the foot of the cliffs, at Punta Arenas adjacent to a small mangrove swamp. The pond seems to be manmade, of recent origin, and was scooped out of sand and swamp deposits about 2 feet or less thick, which overlie truncated reef deposits.

The water surface of the pond was estimated to be about 0.4 foot above mean sea

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WATER RESOURCES DIVISION

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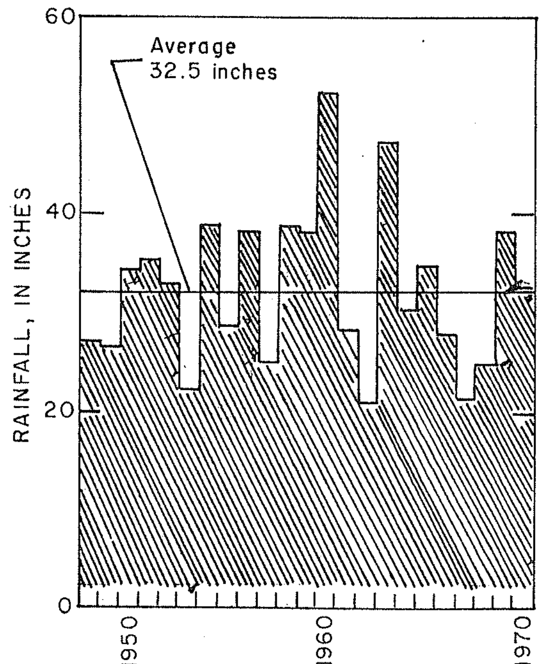

Figure 2.--Annual rainfall, Isla de Mona, 1948-70. U.S. National Weather Service data.

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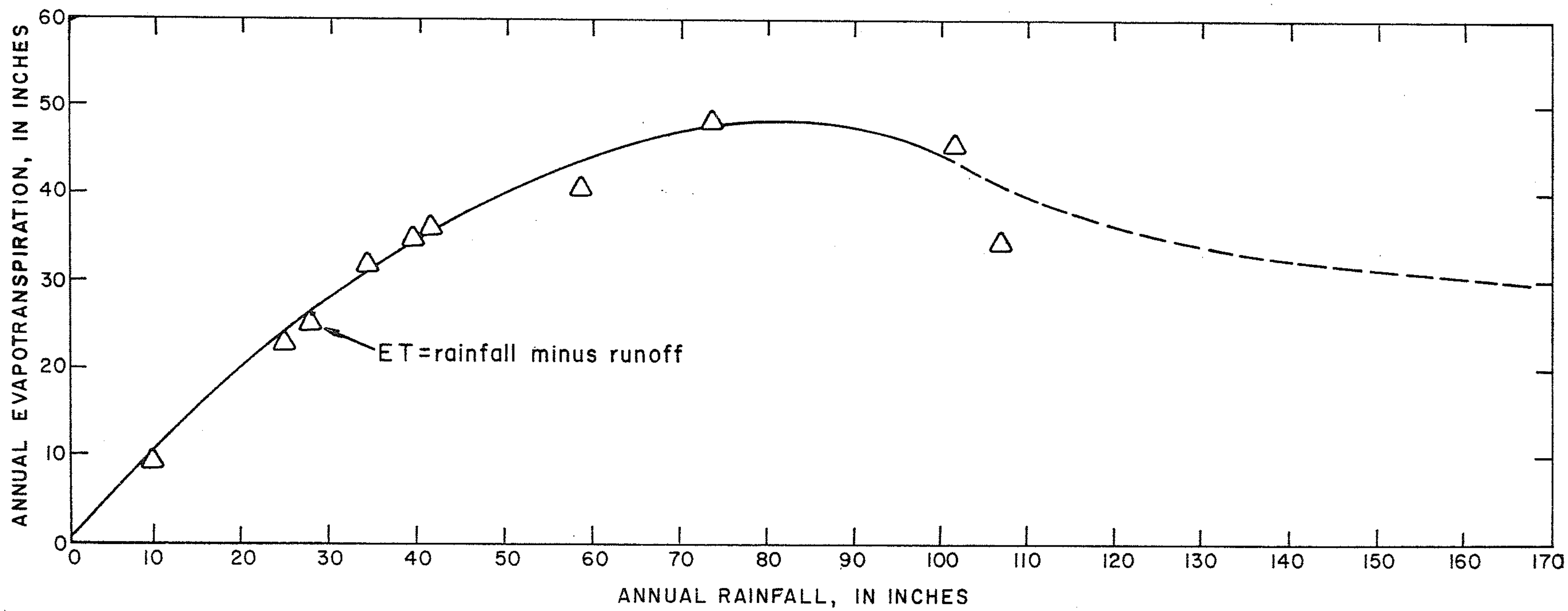

Figure 3.--Evapotranspiration as a function of rainfall in Puerto Rico (E.V. Giusti, written commun., 1971).

level on August 17, 1972, based upon an arbitrary sea-level datum established on the adjacent beach area. Water levels recorded August 16-19, 1972 (fig. 4) showed a diurnal fluctuation that is attributed principally to evapotranspiration by vegetation in and surrounding the pond and ground-water inflow. The fluctuaciones indicate that the pond has little or no hydraulic connection with the sea because there are no evident responses to tidal cycles. Therefore, the pond is likely perched on the underlying reef deposits.

The slight increases in the water level during the night hours are attributed to reduced evapotranspiration and continuing ground-water inflow, probably from the Isla de Mona Dolomite. Night inflow to the pond was about 10 ft^3 (cubic feet) in an 8-hour period. Total daily inflow thus is estimated to be about 30 ft^3, or about 225 gpd (gallons per day). Water-level fluctuations from inflow during the daylight hours are probably masked or compensated for by evapotranspiration.

Ground Water — Brackish ground water has been found in the reef platform and overlying sand deposits of the southwest margin of the island.

Presence of a fresh-water mound in the interior of the island in the Isla de Mona Dolomite may be inferred by comparison with other islands having limestone aquifers, such as in parts of Puerto Rico, Guam, and St. Croix, Virgin Islands of the United States.

Reef and Sand Deposits — Brackish ground water in sand and reef deposits is tapped by dug wells less than 11 feet deep (fig. 1). Wells 1 and 2 penetrate the sand deposit at the foot of the cliff behind Playa Sardinera. Well 1 fully penetrates the sand deposit and bottoms on reef deposits. Well 2 just to the south is abandoned and nearly filled with debris but also seems to be only in the sand. Well 3 at the airstrip penetrates a few feet of sand and is completed in reef deposits. Well 4 has been dug in reef deposits inland of Playa del Uvero. A summary of information for the wells is given in table 1.

All wells are believed to be hydraulically connected with the sea, particularly wells 3 and 4 that tap water in the reef deposits. The hydrograph of well 3 (fig. 5) shows a diurnal fluctuation indicative of tidal control.

Cave Pools — Cueva de Pájaros is the only cave known to contain a permanent fresh-water pool. The pool is a small depression in the floor of the cave. Two theories have been presented for the source of the water in the pool —water dripping from the roof of the cave and ground-water seepage.

Many other caves contain dry rimstone pools 1 to 4 inches in depth and as much as 10 square feet in area. Fresh calcareous deposits on the rims of the pools are occasionally filled with water dripping from the cave roofs. This is probably a wet-season occurrence only.

Water Quality — Water-quality information is available only for the dug wells, the pond at Punta Arenas, and the pool in Cueva de Pájaros. Results of analysis of water

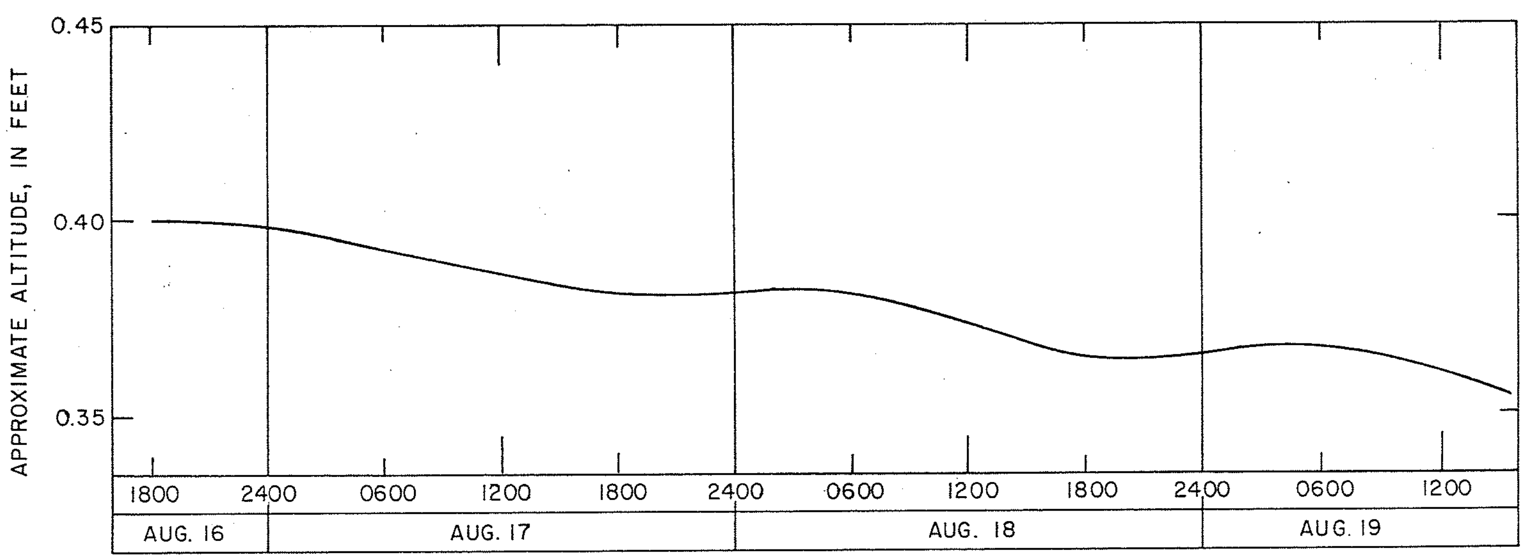

Figure 4.--Water-level fluctuation of pond at Punta Arenas.

Table 1
Geohydrologic data (September 1, 1964)

Location, figure 1	*Depth, feet*	*Water level below land surface, feet*	*Aquifer*	*Remarks*
Well 1	6.0	3.0	Sand	Used for bathing and washing
Well 2	5	3.5	Sand	Unused
Well 3	10.7	7.5	Sand and reef deposits	Unused
Well 4	7.8	5.0	Reef deposits	Unused
Pool in floor of Cueva de Pájaros				Small sump

Table 2
Chemical Analyses of Water on Isla de Mona

Source	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Ortho-Phosphate (PO_4)	Dissolved solids calculated	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Temperature (°C)
		Milligrams per liter																			
Well 1, Pozo	7-30-64	2.5	0.00	—	78	55	—	—	240	0	—	695	0.00	0.2	0.26	—	466	259	2,600	8.0	—
del Portugués	8-31-69	3.6	—	—	91	69	524	11	268	0	117	970	.00	.0	.00	1,920	511	291	3,550	7.8	27
	8-17-72	4.8	.12	.00	98	64	500	20	272	0	120	920	.10	.8	.05	1,860	510	280	3,330	7.8	—
Well 2	8-31-69	3.6	—	—	346	248	1,790	35	717	0	298	3,520	.02	—	.00	6,590	1,880	1,300	11,400	7.8	27
	8-17-72	4.6	.18	.00	180	180	1,400	62	578	0	240	2,600	.4	1.2	.59	4,950	1,200	720	8,760	7.9	—
Well 3,	7-30-64	3.5	.00	—	118	110	—	—	496	0	—	1,090	.5	.2	.06	—	747	340	4,050	8.1	—
airstrip	8-19-72	5.6	.05	.00	120	100	650	25	484	0	140	1,200	.3	.3	.20	2,430	710	310	4,300	7.5	—
Well 4,	7-31-64	7.5	.04	—	122	130	—	—	330	0	—	1,890	.8	.6	2.3	3,900	839	568	6,090	7.8	—
Uvero	8-19-72	8.3	.02	.00	130	130	1,100	48	354	0	100	2,000	.6	1.0	2.6	3,640	860	570	6,370	7.9	—
Cueva de	7-30-64	14	.00	—	36	126	—	—	8	0	—	190	.0	86	3.0	—	608	601	1,560	6.6	—
Pájaros																					
Pond, Punta	8-17-72	22	.00	.00	59	86	490	28	352	0	64	880	.6	3.7	.4	1,810	500	210	3,180	8.1	—
Arenas																					

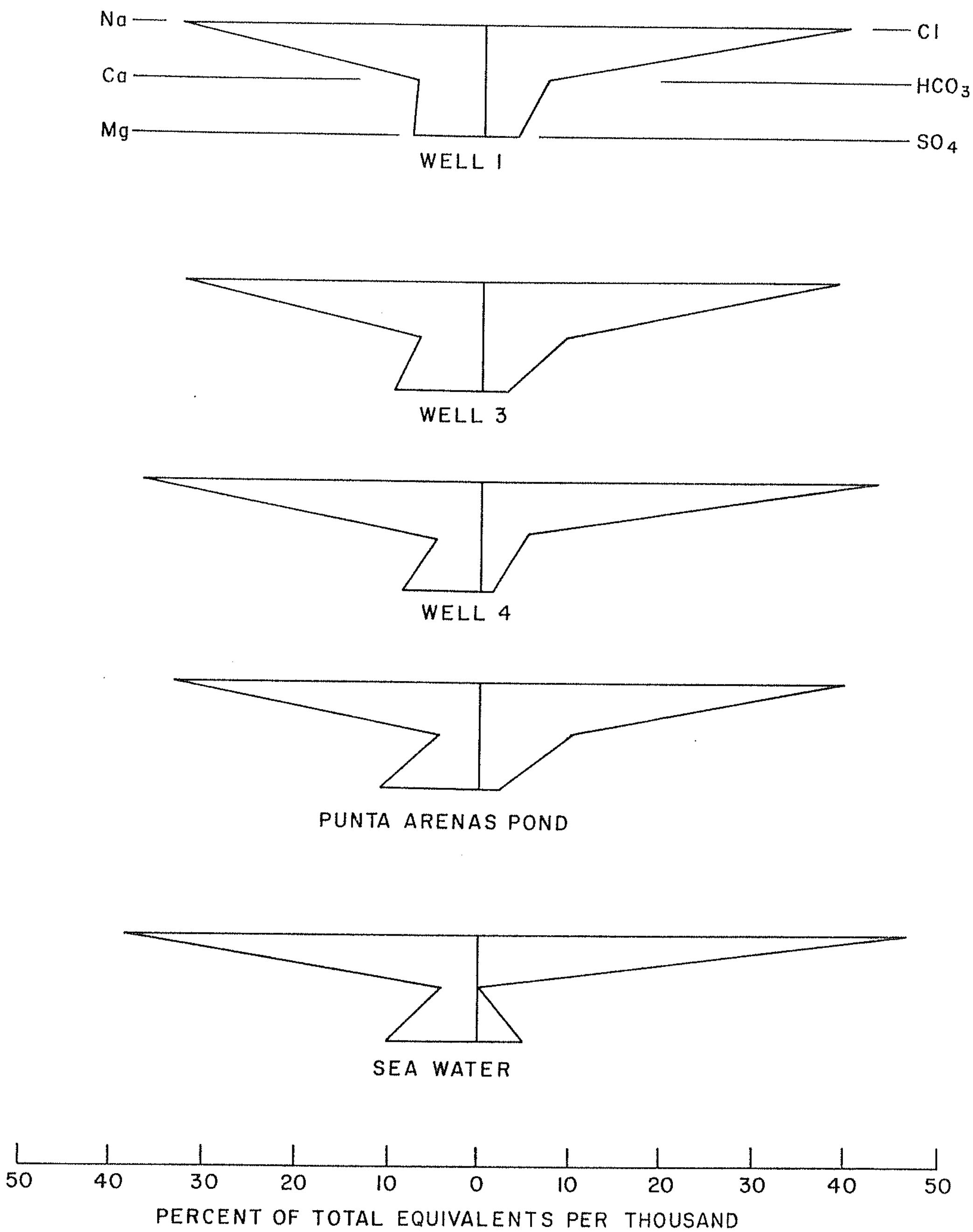

Figure 6.--Analyses of water from various sources represented by polygons.

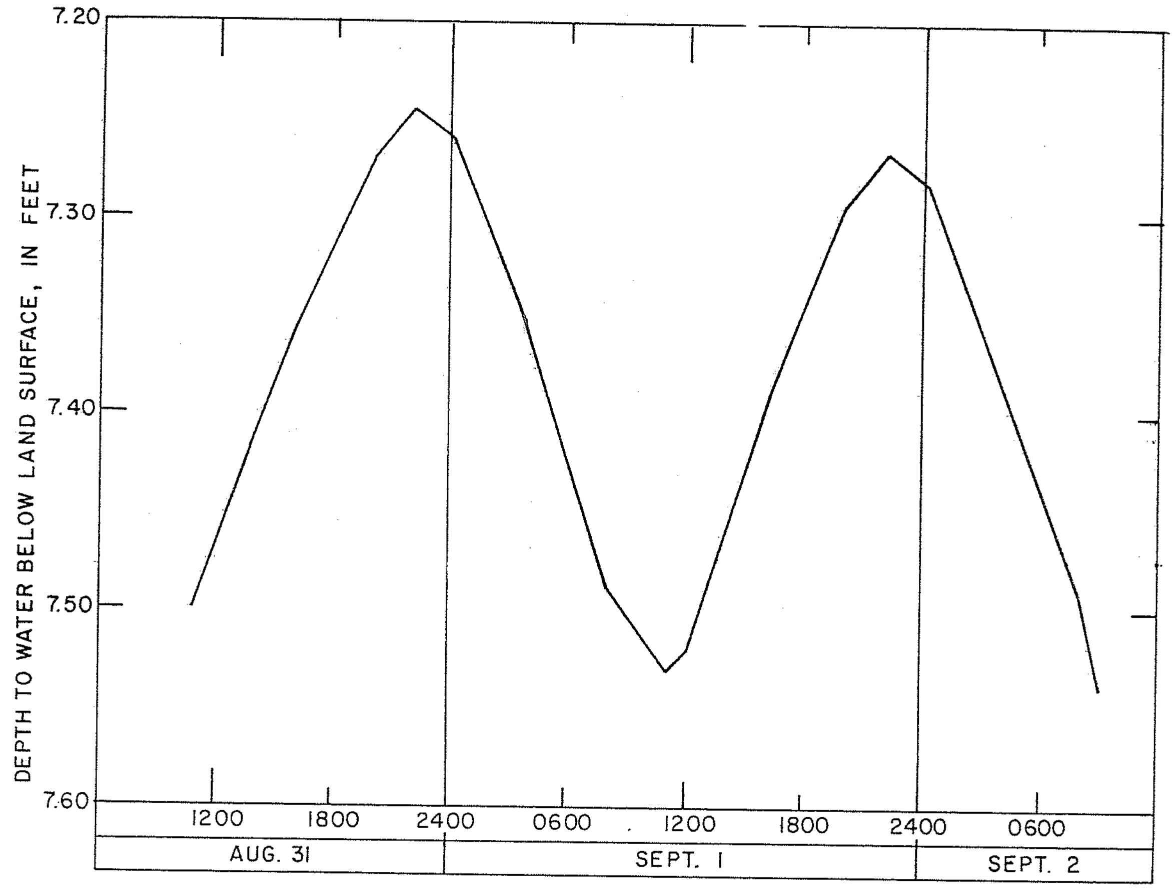

Figure 5.--Water-level fluctuation of well 3, August 31 to September 2, 1964.

from these sources are given in table 2. The water shows a strong resemblance to sea water as shown in the polygon diagrams of figure 6. The source of characteristic sea-water type minerals is probably from mixing in the salt water-fresh water interface and from the concentration of airborne minerals on the land surface that are later carried to the water table with recharge during major rainstorms. In island aquifers, airborne minerals can account for 50 percent or more of the initial mineral content of the ground water (Cosner, 1972). It is estimated that the initial chloride content of ground water on Isla de Mona is about 100 mg/1 (milligrams per liter.)

Water in the pool in Cueva de Pájaros probably is from lateral seepage from the limestone, although it may drip from the roof. The high magnesium and nitrate content of the water is probably derived from guano deposits in the cave.

WATER POTENTIAL

There are two potential sources of water supply on Isla de Mona —rainfall that is a proven source and ground water that is a possible source.

Rainfall Catchments — Rainfall is collected from the roofs of the Agriculture Station and from the roofs of the lighthouse residences and is the only current source of fresh water for the 10 and 5 men, respectively, at these stations. The quantity of rainfall generally proves to be sufficient for drinking and cooking.

Observations made of rainfall catchments on St. Thomas, Virgin Islands of the United States, have shown that large catchments are about 70 per cent efficient. Losses are from light showers that evaporate from the hot surface of the catchment and from leakage. On the basis of this experience, a large catchment on Isla de Mona would yield about 14 gallons of water per square foot in a year of average rainfall. Storage of about 5 gallons per square foot of catchment would probably be sufficient to retain about 90 per cent of the average annual catch. To retain all the annual catch would require more than three times greater storage.

Ground Water — The hydrologic characteristics of the aquifers of a small island or of a coastline are somewhat different from those of aquifers isolated from the sea. Because of this a short discussion of the relationships of fresh-ground water to sea water follows.

The Fresh-Water Lens — Recharge from rainfall is relatively fresh and when it reaches the zone of saturation it accumulates in a lens that floats in and displaces the slighty heavier sea water. As sea water is about one-fortieth heavier than fresh water, the depth of a static fresh-water lens would be roughly 40 times the height of the water level above sea level. However, water moves constantly through the lens from areas of recharge to zones of discharge.

High permeability of an aquifer will allow the free movement of fresh water toward zones of discharge at the shore. High permeability likewise is favorable for the movement of sea water inland; hence considerable mixing of fresh water and salt water occurs. Mixing is facilitated by oscillatory movements of the inter-face between salt water and fresh water caused by fluctuation of tides and recharge.

Mixing creates a zone of transition between the fresh water and salt water in which the water becomes progressively more saline downward and seaward. The transition zone is generally thicker toward the coastline, and as shown in the analyses of well water in the coastal zones of Isla de Mona, extends up to the water table in the shoreline areas as shown in figure 7.

In the matter of water supply, important factors in a lens are rate of recharge, permeability of rocks through which the water moves, and the effects of mixing of the fresh water with the sea water.

Ground Water in the Sand and Reef Deposits – Brackish ground water is available in the reef deposits and overlying sand of the southwest part of the island as has been shown by the existing wells. Ground water of better quality may possibly be obtained from the talus and reef deposits at the foot of the cliffs on the south side of the island. The most favorable location would be inland of the east end of the airstrip (fig. 1) where the reef terrace has its greatest width.

Ground Water in the Calcareous Rocks – The Lirio Limestone capping Isla de Mona Dolomite appears to be very permeable. The lack of surface drainage would appear to verify this observation. The permeability of the underlying Isla de Mona Dolomite, however, is questionable. Observation of the cliff faces shows it to be quite dense with few visible solution openings. The development of caves in the Lirio Limestone at the contact with the Isla de Mona Dolomite is further evidence that the dolomite is less permeable although Briggs attributed initial cave formation to wave action (oral commun., 1969).

If. however, the Isla de Mona Dolomite formed a moderately impermeable surface to the downward migration of rainwater there would be high-level springs, at least during the rainy season, along the contact. None have been reported, so it is assumed that the Isla de Mona Dolomite has sufficient permeability to receive the rainwater that percolates through the overlying Lirio Limestone.

If a ground-water gradient similar to that in the limestones of northern Puerto Rico can be assumed (3 ft per mi), then a fresh-water head of about 6 feet exists in the central part of Isla de Mona, creating a fresh-water lens about 250 feet thick, as shown in figure 7. Hypothetical contours of the water surface are shown in figure 8. The permeability of the aquifer will, in a large part, determine the height and size of the fresh-water mound. The greater the permeability, the more freely will fresh water move seaward and the lesser the height of the fresh-water mound above sea level.

The existence of a fresh-water mound depends entirely on the infiltration of rainwater into the Isla de Mona Dolomite. If ET is as estimated, then the island receives about 4 inches of recharge annually, or the equivalent of 4 mgd (million gallons per day). In turn, ground-water discharge seaward at the perimeter of the island would be about 26,700 ft^3 (200,000 gpd) per lineal mile of coastline. The computed ground-water be about 30,000 ft^3 (225,000 gpd), within 10 per cent of the theoretical discharge.

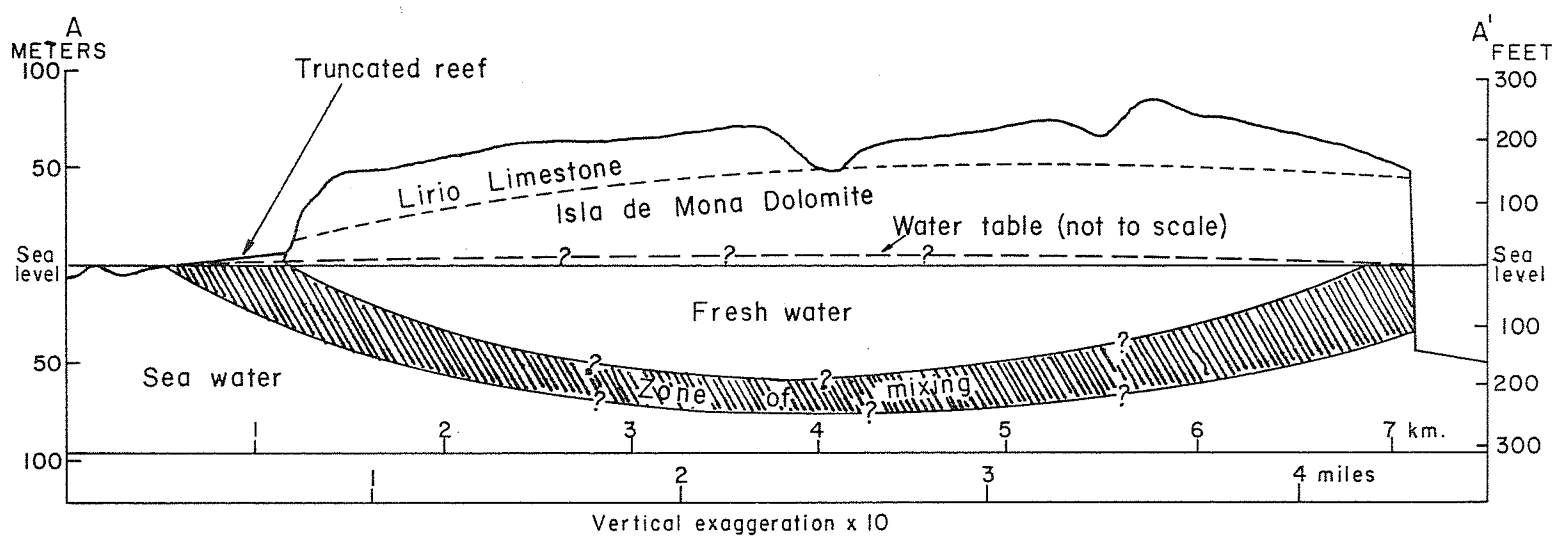

Figure 7.--Hypothetical occurrence of fresh water in dolomite and truncated reef deposits. (See fig. 1 for cross-section location.)

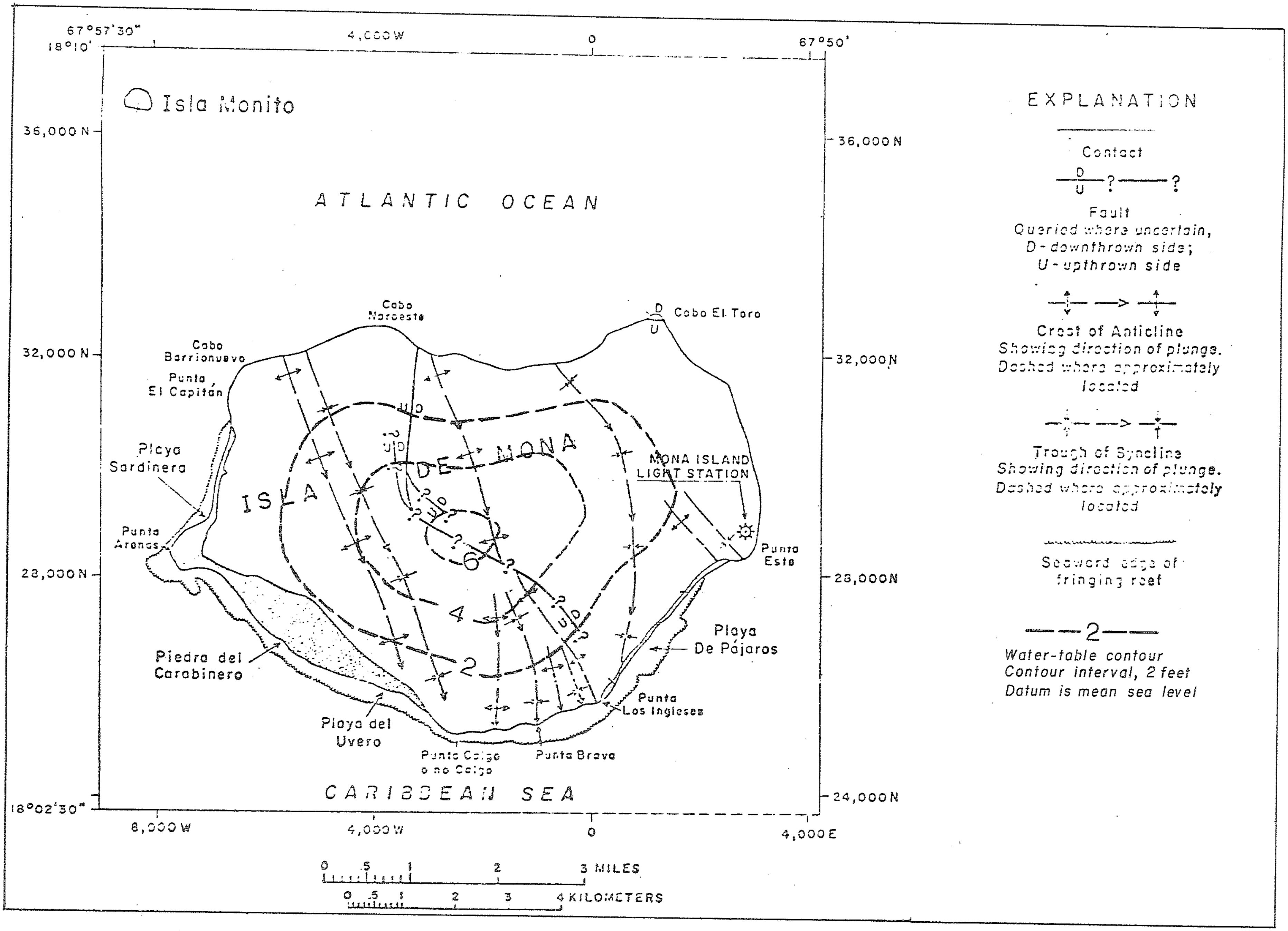

Figure 8.--Hypothetical altitude of the ground-water surfac

Based upon a water-table gradient of 3 feet per mile, a discharge of 26,700 ft^3 per lineal mile of coast, and an aquifer thickness of 100 feet, the hypothetical hydraulic conductivity is about 90 $ft^3/day/ft^2$ (cubic feet per day per square foot). This hydraulic conductivity is similar to that of the limestones of northern Puerto Rico.

Unfortunately, computations can be made for different values of hydraulic conductivity, slope of the water table, and aquifer thickness, and different results obtained, all of which would be hypothetically correct. The key, however, lies in the estimate of recharge from rainfall to an aquifer that evidence indicates may be on the order of 4 inches per year.

Potential Wells Sites – Assuming that a fresh-water mound does exist, the most appropriate location for wells would probably be in the central part of the island where the lens might be thickest. There might also be local ground-water movement toward this area because of the fault zone and synclinal structure in the vicinity of the fault.

Wells tapping the fresh-water zone would be about 200 feet in depth depending on the altitude of the land surface. Depth of penetration of wells below the water table should be kept to a minimum, probably no more than 30 feet, due to salt--water coning under the well that will occur when the fresh-water head is lowered by pumping. Wells no more than 6 to 8 inches in diameter might be desirable as the small diameter would to some extent restrict the size of the pump and potential production thus helping to protect the aquifer from overpumping.

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Apéndice: E

Pelagic Life Around Mona Island

By

Donald S. Erdman
Puerto Rico Department of Natural Resources

Mona Island is characteristic of a tropical islands surrounded by deep seas. Most of the life including some terrestrial fauna is typical of the deep sea such as tropic birds, red-footed boobies, Audubon shearwaters and Wilson petrels; brown noddy terns; humpback whales; man-o-war jellyfish *Physalia*; white-tip sharks; flyingfish; *Sapphirina*, and others.

Literature on the pelagic life around Mona Island is scattered through various journals. Erdman (1956) discusses a few shore and pelagic fishes; (1958) Foods of pelagic fishes (1965), luminescent worms; (1967), sea birds; and (1970) and Caldwell & Erdman (1963) whales and dolphins. Caldwell and Erdman (1969) list the Ridley turtle off San Juan which could also occur off Mona Island. Various FAO reports list some experimental fishing off Mona Island. Bullis (1959) during the OREGON cruise in October said "In Mona Passage, scattered large tuna were observed on one occasion".

The author has made observations on and around Mona Island on 16 trips since 1946. The following months have been included: February, 1; March, 1; April 1; May, 4; June, 3; July, 2; August, 2; September, 1; October, 1.

Mona Island is a natural laboratory located on the high seas. It is a good place to collect year around observations on the seasonal changes of life in the sea. While changes of sea life from winter to summer are less marked than at Barbados, Lewis and Fish (1969), seasonal changes in the plankton and nekton occur around Mona Island and may be expected to become more evident after more year-around information is secured. Characteristic fauna of the four seasons are listed on Table 1.

Weather patterns are different enough seasonally to have considerable influence on plant and animal life on the island and the seas around it.

Seasonal changes in weather around Mona Island are less marked than in temperature regions. San Juan has an average daily high temperature of 80° F. in January to 86° in September. Sea surface temperatures vary from about 79° in winter to about 85° in summer. Average daily low air temperatures vary from 69° in February to 75° in September.

Weather patterns do change seasonally in spite of the small average temperature changes. Winter is characterized by ground seas caused by large waves coming from slightly west of north from Atlantic winter gales. Spring is windy although July happens to be the windiest month. Summer is hottest with the most amount of rain usually in September. Autumn has light winds and calms; October is the calmest month.

Actual weather patterns do not exactly coincide with the change of seasons nor are they the same from year to year; but there is more or less a consistent pattern of the years which is well understood by fishermen.

January is the month usually with the most north winds and ground seas which make Mona Island dangerous for anchoring in its small ports. The seas tend to draw all around the island in heavy weather.

February has lessening ground seas but harder easterly winds which fishermen associate with the period of Lent. March frequently has a few calm days around the middle of the month when great islands of *Sargassum* may accumulate on the top of the sea. Winds soon resume and blow the sargassum westward.

April, May and June are windy months, but sea conditions are generally good. July is the windiest month, and nasty squalls are not uncommon. Although August is a month with some hurricane danger, it is usually characterized by good weather with moderate breezes.

September is the most dangerous hurricane month, but otherwise the weather is fair. It is the best month in the year for blue marlin fishing.

Late October or early November is the time of the first ground sea which makes the spiny lobsters run into the pots or "nasas". It is also the time for good octopus catches.

November is consistently the best month for sailfish. it is generally calm up to the middle of the month but occasionally squally in the second half of the month.

December can be very windy or relatively mild, but except for groupers it is now one of the better fishing months of the year.

There is a strong counter –current in the Mona Passage that sets northeasterly in direction against prevailing winds.

There are also tidal currents' The Coast Pilot 1939 p. 173 said that at Sardinera (Mona Island) the flood sets northward and the ebb southward at 1/2 m.p.h.

The seas around Mona Island are generally rough and confused because of strong currents contrary in direction to prevailing winds.

The hawksbill turtle *Eretmochelys impricata* lays eggs on the sand beaches of Mona Island. The beach at the southwest corner of the island called Isabela anchorage is frequently used by sea turtles. It is possible that an occasional leatherback turtle could nest there, but apparently most of them choose to nest on beaches of Puerto Rico proper. The green turtles nest in large colonies in Costa Rica, Mexico and Aves Island. The loggerhead turtle *Caretta caretta,* nests along the south Atlantic coast of North America. The Ridley turtle is known to nest off North Coast of Brazil and the Guianas.

On a rare calm morning at dawn you may look down into the clear deep sea south of Pájaro Beach and see tiny blue dots with an intense irridescent blue reflecting the early rays of the sun. These are small copepods know as *Sapphirina*.

The floating plant life in the sea is called phytoplankton which is the most important basic food of the animal life or zooplankton. Most of the phytoplankton are microscopic one-celled algae which are capable of carrying on photosynthesis.

Flotsam is the name given to floating material on the surface of the sea, such as pieces of wood, plastic bottles, etc. In addition there are floating remains of dead plants or animals. These dead plants or animals are important as they are indicators of surface current drifts as well as prevailing wind directions.

In winter, cuttlebones of *Sepia officinalis* are washed up on West Indian beaches; and yet the cuttlefish does not occur in the Western Artlantic; it is native to the eastern Atlantic off Europe and the Mediterranean. In other words they drift all the way from Europe or Africa. Likewise the small white spiral shells of *Spirula* occur on the beaches in winter.

During late summer the ocean currents are more from the southeast and the "coquitos" or sleeve palm fruits of *Manicaria saccifera,* which is native to the lower Amazon river, drift on to the beaches of the south coast.

RECOMMENDATIONS

Mona Passage is an important channel for the passage of ships of commerce. Since the waters are international, it has been rumored that occasionally ships wash out their oil tanks at sea eastward of the Mona Island lighthouse, and the oil drifts up on the Mona beaches. This practice should be reported when it occurs and be discouraged.

Table 1
Animals characteristic of Pelagic
Life around Mona Island by seasons

Prevailing species by seasons	*Winter Jan. - Mar.*	*Spring Apr. - June*	*Summer July - Sept.*	*Autumn Oct. - Dec.*
Sea birds	jaegers	sooty-terns	brown noddies	red-footed boodies
	Audubon shearwaters	Wilson petrels	bridled terns	frigate birds
	white-tailed tropic bird	Leach's petrel		
cetacenas	humpack	dolphins	"blackfish"	dolphins
fishes (sharks)	fewer sharks seen	silky shark	white-tip shark	whale shark
billfishes	sailfish	white marlin	blue marlin	sailfish spearfish
tunas	bluefin tuna: rare	blackfin tunas	yellowfin tunas	large but fewer
			large skip jack (bonito)	yellowfin tunas wahoos
dolphins fish or "dorado	most dolphins	many dolphins	pompano dolphins occasional	return of large dolphin
forage fishes	doctorfish filefish	butterfly fishes	juvenile tunas	goatfishes triggerfishes *Xanthichthys*
	Pseudoscopelus flyingfishes	needlefishes flyingfishes		
mollusea	*sepia Spirula*	Argonauta Atlanta	squids	octopi
crustaceans	sargassum crabs	brachyuran crab megalops	stomatopod larvae	
		Coenobita larvae		
jelly fishes	*Physalia*	*Physalia*	Otenophora	*Aurelia*

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Apéndice: F

Preliminary Assessment of the Marine Resources of Mona Island

Edited by

Francisco A. Pagán-Font

Department of Marine Science
University of Puerto Rico

SCIENTIFIC PERSONNEL

Máximo J. Cerame-Vivas	Observer (Guest Scientist)
Francisco A. Pagán-Font	Chief Scientist
Jack Morelock	Marine Geologist
Francisco Guzmán (MD)	Medical Services
Walter Hendrick	Chief Underwater Operations
Gilberto Cintrón	Guest Scientist
José A. González-Liboy	Research Associate
Alida Ortíz	Research Assistant
Edgardo Ortíz	Research Assistant
Jeffrey Prentice	Research Assistant
David Fast	Research Assistant
Dennis Jordan	Research Assistant
Richard Wallace	Research Assistant
Ricardo Cortés	Research Assistant

RECOMMENDATIONS

1. A detailed study of the marine resources of Mona Island is needed. Duration of the study should be at least two full years. Such a study would be best performed through the establishment of a permanent research station, from which all operations could be carried out. The facility could be constructed and equipped in such a fashion as to allow for terrestrial, aquatic and marine scientists to conduct their work. Results of the comprehensive study would serve to set the guidelines for the future development of Mona.

2. A permanent facility should be built on Mona Island to be employed in studies of short or long range nature. Scientists could be stationed in Mona on short or long-tour basis. In this way inputs from many parties would be utilized. Priority should be given to Puerto Rican institutions or agencies to conduct such studies.

3. Approximately, 2,000 acres of land should be set aside for use in scientific endeavors. However, within these 2,000 acres, low intensity usage by the public could be permitted.

4. Areas on the insular shelf of Mona should also be reserved for scientific purposes. These areas should include, the bottom, the water column and the shoreline.

5. Studies of marine populations inhabiting the coastal waters of Mona would permit a better understanding of these resources. The results would allow for development of management techniques applicable to populations which are amenable to scientific exploitation or harvesting. The developed management techniques could be applied to similar populations in Puerto Rico.

INTRODUCTION

This preliminary assessment was undertaken by a group of scientists and laymen who volunteered their services. Their efforts were oriented toward obtaining much needed knowledge on coastal waters and the littoral resources, which are of great significance to the island as a whole.

Mona (with Monito) belongs to the group of enchanting small islands which make up Puerto Rico:s island system. It is one of the two islands (Desecheo being the other) off western Puerto Rico. Mona is the largest of these western islands. It is perhaps the most beautiful and mysterious of all of Puerto Rico's satellite islands. Part of its history is that of Puerto Rico, but Mona can also claim its own historical events. Legends and fantasy are part of that history. Because of these elements, since early times Mona has had an identity of its own.

For decades, the terrestrial environment of the island has been studied, but very little is known about Mona's coastal and underwater worlds.

BACKGROUND

This report was written from information obtained through field observations, collections, and literature review. Perhaps the most significant contributions to the report emanated from personal interviews with fishermen, government officials and other parites who for years had been familiar with the marine resources of Mona. People interviewed belonged to all walks of life. Much of their information was corroborated during the field survey.

The field portion of the study was conducted intensively during the period from September 1 through September 4, 1972.

Because of the magnitude of the mission and the time limitation, the work was divided into several operational areas. The task force was divided correspondingly into sub-groups. The areas under consideration were the marine flora, the marine invertebrates, the marine fishes of coastal and coral reef nature, the underwater world in general, the queen conch *(Strombus gigas)* the West Indian topshell *(Cittarium pica)* and the spiny lobster *(Panulirus argus)* resources, the sand beaches, and the marine geological aspects of Mona.

The report does not present a complete picture of marine resources. It gives rather a partial overview of their potential utilization and value, possible courses of action leading toward their rational development and conservation, and their importance or significance relative to similar resources found on mainland Puerto Rico.

MONA COASTS *(Morelock)*

The island's coasts, from Punta Este along the North and Northeast capes through Cabo Barrio Nuevo (and one mile beyond), is predominantly cliff type. Beyond El Capitán Cave through Punta Oeste, the coast consists primarily of a wide expanse of excellent white sand beaches with small patches of rocky shores. Beyond Punta Oeste and extending all the way to Punta Este, the coast conditions are again prima-

rily white sand beaches, alternating with patches of rocky shores. The beaches of Mona include Playa de Pájaro, Sardinera, Isabela, Carabinero, Uvero, El Playazo, La Pocita, Los Ingleses, Playa Brava, and Playita del Caigo.

UNDERWATER WORLD OF MONA *(Hendrick)*

This section deals with observations made during a series of dives to investigate the relatively deep water along the north coast; the precipitous shelf break on the south, and the surge channels that dominate the outside of the barrier reef on the west.

Objectives

Due to the limited time for underwater explorations, tasks were limited to visual impressions of corals, fishes, rocky environments, caves, tunnels, vegetation, visibility and shipwrecks; documenting with 35 mm photos whenever possible and emphasizing those features that distinguish underwater Mona as unique; or contrast with earlier observations since 1958 on Mona or with those made in Puerto Rican waters.

Dives

Seven dives were made as follows:

1. Cabo Noreste (Northeast Cape) —divers descended to a maximum depth of 100 ft. and swam with the current, east to west, visually scanning the wall and bottom characteristics for an approximate distance of 125 ft.

2. Lado oeste (West side) — 18 degrees 0.06 minutes north— 67 degrees 56.3 minutes west-divers swam depths ranging from near surface to thirty five feet and covered approximately 600 ft. to the south.

3. Suroeste (Southwest) —18 degrees 0.44 north— 67 degrees 56.3 minutes west-divers skin dived and made brief observations at 60 to 80 ft.

4. A half mile east of Cabo Noreste divers entered the water close to the wall checking small caves, fishes, and rock habitats. They swam with the current, east to west, for about 1000 ft. at depth of approximately 40 ft., making occasional excursions to depths of 80 and 90 ft.

5. From where number two terminated 1200 ft. to the south.

6. About half way between West Point and Uvero Anchorage on the south coast at 18 degrees, 0.0415 minutes —67 degrees 55.6 minutes— divers descended to 150 ft. along the vertical shelf break.

7. From the location of dive number two to Cabo Barrio Nuevo.

Combined observations from seven dives

The north wall descends almost vertically to depths of 90 and 100 ft. Along its face grow huge basket sponges oriented horizontally rather than the usual upright position. Gorgonian corals and plants also aligned at right angles from the cliff face undulating vertically as wave energy dissipates over their flexible forms. Below them, where large slabs and boulders of cliff material have fallen, are ocean surgeonfish, red snapper, yellow tail, school master, queen and french angels, rock hind, red and Nassau grouper, giant parrotfish, rock beauties, margate, and jacks. Fish seem larger and certainly in greater abundance than noted in other waters of similar depth and habitat characteristics around Puerto Rico. These conditions were true because of the prevailing undisturbed conditions. Vertical visibility was 90 ft., whereas horizontal visibility exceeded the vertical on that day. A timed swim with the current by one diver estimated the visibility at 150 ft.

Barracudas swimming in pairs or alone were spotted. One sea turtle slightly more than three feet across swam near the divers, seemingly interested in what they were doing.

A current of approximately 60 feet per minute moved from east to west along the cliff face at the surface and below. Waves breaking along the face sometimes found small caves at the air-water interface. A tremendous force of energy is expended here, driving great volumes of water into the entrances. Divers would be prudent to avoid this type of interface. As one swims away from the cliff face underwater at depth, the rocky environment diminishes and a sandy rather barren bottom emerges. A few small encrusting corals can be seen on limestone slabs and boulders.

A very exciting area is the drop off on the south. Just a few hundred feet from shore the continental shelf breaks at 50 and 60 ft. The break is shear with a precipitous drop to 150 ft. where a narrow terrace coated with calcareous sediment extends further south and once again drops dramatically to a greater depth.

The water is blue and clear. Soft gorgonian corals flourish in spectacular abundance along the vertical face. A thermocline seen as a change in light refraction and felt by the diver's flesh is easily detected at 130 ft. A stratification of marine growth is noted while descending, and forests of black coral appear around 140 ft.

Above, at depths of 50 and 60 ft., massive corals with vertical reliefs of 15 and 20 ft. are just off from the continental shelf. They appear healthy and extremely well nourished. Fishes of many species swim over, around and into them, while overhead swim barracudas, amberjacks and blue runners.

Like the north wall, basket sponges project out horizontally, resembling cannons protruding from a ship's side. On the deepest inside face lives a hard coral at a depth of 110 ft. Soft corals, delicately laced, shoot out horizontally with their broad faces to the current moving from the east. They sway attractively with the gentle surge but hold slightly to the west, yielding to the current. The corals are unusually large and their numbers are once again much higher than noted in our local waters.

Current velocity in this area is about 80 ft. per minute to the west, at a depth of 80 ft. A diver hanging onto fixed objects resembles a flag in the wind. The current is

noticeably reduced below 130 ft. A nurse shark about 5 to 5 1/2 feet in total length swims lazily by at the continental shelf and continental slope interface, totally ignoring the two divers as they photograph the lush garden of soft corals. Visibility is approximately 100 ft. The second drop off at 150 ft. is easily seen, but special dives with special equipment are necessary for its investigation.

Slightly south of Cabo Barrio Nuevo a barrier reef forms in front of a shallow water lagoon spotted with corals. Surge channels extend from the reef to the west, some forming caves large enough for divers to swim in and about. The channels farthest north are heavily laden with cobble stones which diminish as one swims away from the reef seaward. Fish collecting stations have been established both in the lagoon along the rocky shore and seaward to depths of approximately 20 ft. One can readily see the great diversification of species just by sitting on the bottom and watching the fishes and their performance.

The surge channels offer many nooks and crannies for fishes to hide and from which to venture away from the reef proper. An impressive number of "royal grammas" are to be found swimming upside down in these zones. Few sea urchins inhabit these rocky environments. Queen trigger fishes are plentiful. Hard corals encrust much of the limestone base. Gorgonians, while not in abundance, decorate the bottom in colorful fashion. Many flamingo tongue shells were seen attached to sea fans. Red snapper and grouper were seen swimming close to the westward edge of the channels only to then swim quickly away towards deeper water. Barracudas frequent the reef front in pairs. One green moray eel was spotted in a surge channel and two very small spiny lobsters were seen nearby. A current of about 50 ft. per minute moved from south to north and visibility was estimated at a depth of 120 ft. On the morning of the fourth of September as the ship's anchor was being hauled aboard, the visibility was estimated to be 200 ft.

General remarks

The physical characteristics of underwater Mona are vastly different from those in underwater Puerto Rico. One can see and investigate a wide diversification of bottom profiles within the short distance of six miles. Visibility is certainly desirable if not a must for accurate and detailed underwater explorations. Such conditions may be found in most of the coastal waters of Mona. Corals yet unaffected by industrial effluents offer comparative studies for marine ecologists who are now analyzing the deterioration of coral colonies in polluted zones.

After vast underwater experience in Puerto Rico waters the author appreciates the aesthetic value of underwater Mona. While the number of edible type of fishes, such as the grouper and snapper, seem to have diminished since 1958, those remaining certainly have not altered their behavior. The effect of man's predatorial presence is measurably noticed as one swims about in less harmony with his cold blooded neighbor. One can recall similar experiences and observations when diving in the waters off Fajardo during the late fifties and into the early sixties. Those times were a critical period when man as an underwater hunter invaded a productive area and reduced its productivity to a paltry level, where divers now rarely see large fish and spiny lobsters.

The bottom constituents around Mona are free from river run-off. Plants, invertebrates, and vertebrates not yet described are waiting detection. The dropoff on the south is a virtual paradise both aesthetically and scientifically. It is a blend of nature's beauty and it's hidden treasure of scientific knowledge. Let one not damage or possibly destroy a creation which can not yet be truly appreciated for its total being. Instead, let one protect it, investigate it with all available forces.

SAND BEACHES *(González-Liboy)*

This report concludes a preliminary survey of the beaches of Mona based on previous research, literature, interviews, and recent field observations.

Approximately three miles of the coast of Mona are beaches. These are practically all composed of coarse white sands deposited on the western, southern and southeastern shores. The sands are moderately well sorted, and their principal sources are nearby reefs. Reef-protected beaches can be found at Playa de Pájaros, Playa Brava, La Pocita, and Sardinera, whereas exposed beaches are present only in the vicinity of El Playazo. Seasonal variations in beach character occur. Great amounts of beach material accumulated on the shores during certain months of the year may be washed away during others.

From a physical point of view, the beaches of Mona represent an excellent example of the natural dynamics of beach formation and variability, since no man made structures such as groins, breakwaters or jetties are present. Secondly, because of the island's lack of rivers, beach controlling forces are almost exclusively marine. No other beach in Puerto Rico possesses such attributes. So in this sense, the beaches of Mona are unique.

The beaches of Mona are also very well suited for biological study. Although there are some base line surveys on Puerto Rican beaches, beach fauna studies in Mona are practically non-existing, and the number of recorded species is relatively low. This represents a potential scientific resource and challenging opportunity for those interested in the beach and near shore macro-benthos.

The island's beaches serve also as spawning or hatching grounds for sea turtles. The beaches constitute nesting sites to which the turtles come to lay their eggs. At least two species of sea turtles use the beaches of Mona These are the green turtle *Chelonia mydas* and the loggerhead turtle *Caretta caretta*. Dr. Archie Carr, an authority on sea turtles, has classified the beaches of Mona as minor nesting beaches for the green turtle. According to Carr, there is only one major green turtle nesting area in the Western Caribbean: Tortuguero in Costa Rica. Mona is one of the minor nesting areas. In Mona, nests have been observed on the following beaches: El Playazo, Los Ingleses, Pájaros, Playa Brava, and Playita del Caigo. According to Luis Mendoza, a longtime Mona fisherman, the peak of nesting in Mona comes during the months of September, October, and November. The duration of the nesting season is known to vary from one region to another.

Most of these sea turtles are already under unprecedented fishing pressure. Some of these have been included in the list of endangered species. The beach is the only natural place where these animals will reproduce. The biological processes involved

are delicate and very vulnerable. Alterations to the beach environment could make the beaches unsuitable for mating, while increased human activity may prevent the turtles from coming in.

It is imperative that the beaches of Mona be kept in their natural state. Not only for their scientific and/or aesthetic values but also for their significant role in maintaining some of those natural processes from which present future generations will be able to learn and learn to enjoy without destroying.

MARINE FLORA *(Ortíz)*

Algae

Two main localities were sampled intensively in respect to algae; Sardinera Anchorage on the west, and Playa de Pájaros Anchorage on the east. The collections consisted primarily of 50 species of macroalgae. Observations indicated that densities of these algae were relatively low.

The feasibility of utilizing some of the collected algae to extract drugs or other substances of the sort was not evaluated. Perhaps the latter possibility merits detailed assessment.

The shallow water algae appeared to be similar in diversity to those of mainland Puerto Rico, particularly those of the rocky shores. For instance, the association between *Sargassum-Turbinaria* was seen frequently along the rocky shores of Mona. The lack of previous records or literature on algae from Mona made this portion of the assessment difficult.

Mangrove

Only a very small patch of mangroves, of approximately 0.5 acre, was found, inland about one mile east of Punta Oeste. The mangrove community consisted of *Rhizophora mangle* and *Laguncularia racemosa.* The characteristics of this mangrove growth were obviously different from those found normally in Puerto Rico.

Thalassia or turtle grass.

Thalassia beds were scarce along the entire coastal bottoms of Mona. In the areas where these beds were found they offered shelter and substrate to various animals and plant forms. The Thalassia blades may serve also as a good food source for invertebrates and fishes dwelling in or grazing over the Thalassia beds. The growth of Thalassia at Mona exhibited similar characteristics to that of the coasts of Puerto Rico.

General remarks

From this very brief assesment it would be difficult to make any earth shaking reccommendations. Nevertheless, it is obvious that the marine flora of Mona offers

an excellent area for further and more detailed investigations. The need for these careful and detailed studies cannot be overemphasized.

It is impossible to measure the "economic" importance of the marine flora in terms of their individual values. It must be kept in perspective that many of these plants serve as food for myriads of animal forms such as the well-known "carrucho" or queen conch, the "burgao" or West-Indian topshell, shrimps, fishes, and small animals, which in turn serve as food for larger fauna. Many of these animals are of high value to commerical fishermen from western and southwestern Puerto Rico. The presence of benthic algae and of *Thalassia* beds may be of importance as well in their contribution to bottom stability and sediment collection and accumulation in areas where these plants thrive.

In short, as is the case with most studies of this nature, much more information is needed and much more of it is there "waiting" to be evaluated. A marine botanist would be in paradise studying the marine flora of Mona. The marine flora of Mona makes possible basic or applied investigations in an area with relatively minimal human disturbance (compared with mainland Puerto Rico), although some progressive pollution is already evident at the Island.

MARINE INVERTEBRATES *(E. Ortíz)*

The assessment of the marine invertebrates was limited in general to Playa de Pájaros Anchorage (East coast) and Playa Sardinera Anchorage (West coast). Too small a portion of Mona was covered to really do justice to its marine invertebrate fauna.

Playa Sardinera Anchorage is protected all along its extension by a belt of coral reefs located at a distance of about 100 ft. from shore. The windward side of these reefs was not surveyed. On the other hand, the leeward side was covered in some detail. The protected side exhibited a bottom consisting of patches of coraline structures and aggregations of coarse particles of sand alternating with growth of macrobenthic algae.

The leeward area of the reefs is similar in general characteristics to the forms found on the north coast of Puerto Rico. The two areas differ, in that, in Sardinera Anchorage, for example, a small number of colonies of *Acropora palmata* (Elk horn coral) were found just two or three meters from shore. This was most common on the area north of Sardinera just off El Capitán Cave.

Of the species collected in Sardinera the most exciting and rare was a small Hemichordate found buried in the sand. Identification of the specimen has not yet been completed. Because of the lack of systematic works on Puerto Rican hemichordates, it might still be some time before accurate identification of this organism can be made. Another interesting finding was that of a deep water Medusa (jellyfish), which was caught in very shallow water near shore. Apparently, the form had drifted in with the current the previous night. A third interesting occurrence was when dense plankton populations, including thousands of ctenophores, were seen very close to shore in waters of only 2 meters in depth.

Playa de Pájaro is characterized by beautiful white sands and strong currents and

heavy surge which tend to prevail most of the year. Due to the last two conditions only a few organisms were collected in the area.

General remarks

Time limitation did not permit the intensive evaluation that the marine invertebrate fauna of the island deserved. However, there were indications, as witnessed from the apparent uniqueness of some of the findings, that even in such a brief survey the resource constitutes a most significant asset.

Highly significant is the fact that coral reefs offer natural protective barriers to all sand beaches of Mona. Alteration of these reefs would adversely affect the makeup and extension of these beaches. Mona, as an oceanic island surrounded by very deep waters, is frequently pounded by heavy seas. It would be catastrophic to leave these sand beaches unprotected and exposed to high energy waves.

FISH RESOURCE *(Prentice)*

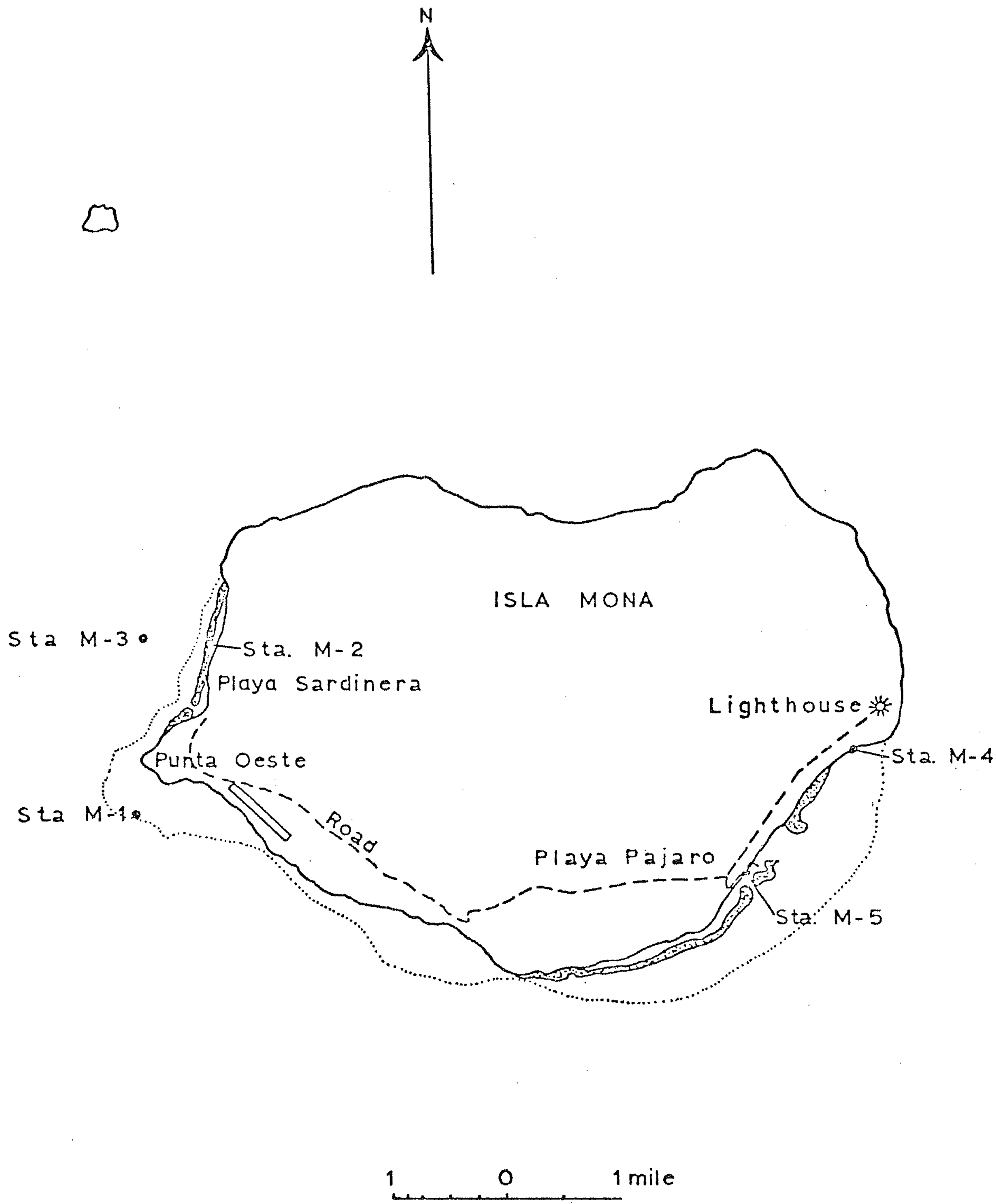
This portion of the study dealt mainly with coastal fishes in general and in more detail with reef fishes. From 2 September through 4 September five collecting stations were established. The information obtained during that period will supplement previous findings and will also assist in the planning of future icthyological and fisheries investigations. The study was undertaken knowing that within the time limitations it could not be a complete assessment of the fish populations of Mona. Much more data are required before a reliable check list of the fishes of Mona can be made. Mona island, at first glance, appears to have ecological areas which are distinctive and unique in shape and form. Within these zones fish will be found in higher densities as compared with similar areas in Puerto Rico.

Description of the collecting sites

The collection of fish was made from five different areas which were labeled (on the map) M-1 through M-5. The most significant area in terms of collected diversity of fishes was station M-1. At this station poison was used at a depth of 70 feet. This method of collection at this depth is uncommon, and the results are interesting. The station was located about 0.60 mile to the south of Punta Oeste. The area was about 120 ft. from the shelf edge where it broke and gradually sloped down at about a twenty degree angle.

The area to be sampled consisted predominantly of hard and soft corals running north and south. The finger-like corals were interspersed with sand which was about two feet lower than the coral. On the surface of the water there was a westerly current of about 0.75 knot, but on the bottom and as far up as 50 feet off the bottom the current was negligible. The current on the bottom was estimated at 10 ft. per minute.

Station M-5 appeared to be quite typical of the bottom in this area and in fact is probably quite typical of the deeper water on the entire south coast. Visibility at this spot was in excess of 100 feet and many fish could be seen.



Map showing fish collecting stations. (Prepared by Jeff Prentice)

The second collection, at Station M-2 was on the fringing reef on the west side of the island about half way from the dock at Playa Sardinera to the cliff toward the north. Quinaldine, a fish anesthetic diluted with Acetone, was used to stun the fish; however, it was found that the current over the fringing reef was too strong, and the fish were not exposed to the anesthetic long enough to be affected by it. Only two species of fish were collected here.

The third station, designated M-3 was the ship itself while at anchor. Non-sophisticated gear was used. Hand lines with a hook and sinker appeared to be the most popular rig. Squid, octopus, shrimp and the flesh of some of the smaller fish caught were used for bait.

On Sunday, September 3, part of the task force traveled by vehicle to Playa de Pájaro Anchorage. There a small dead coral shelf on a shore was visited. The area is just below the U.S. Coast Guard Lighthouse. This rough shore had been subjected to erosion, and many small pools remained behind in which many small fish were seen. The pools are continously filled by the rolling surf. In these holes and puddles as much as 15 feet above sea level are found some of the hardiest and quickest fish. They have to be to survive in that area. The fish which live there either have the ability to hang on with a suction cup or adhesive disk or they have the ability to jump from pool to pool to reach a higher or lower level. The fish here belong to the families of *Gobisocidae, Blennidae* and *Gobiidae.* The fish were tranquilized with a few drops of rotenone in each of the pools and then collected with the help of a slurp gun or hand net.

At Playa de Pájaro the crew also hauled a 100-foot seine down the beach. There were two successful hauls, one starting about 100 feet to the south of Playa de Pájaro dock and working toward the south. The sand on this beach is white but already man has left his mark in the form of oil pollution. This oil has probably reached the beach from tankers from which oil is dumped as they pass east of Mona Island. It was impossible to walk on the beach without having oil or tar stick to one's feet.

General remarks

An accurate check list of the fishes of Mona island will be available as a result of this trip and several others made previously. To date, over 270 species of fish have been reported from Mona waters. Diversity goes on one side from the notoriously famed sharks, barracuda and moray eels to the peaceful, beautiful and intriguing parrotfishes, royal grammas, the trunkfish, the clingfishes, the wrasses, and the goatfishes.

One of the most interesting observations made during the assessment of the fish populations was to see divers and fish sharing the same areas, without the latter darting away from the presumably human predators. Such fish behavior is a good evidence of minimal disturbance by man. Sadly, this same type of condition is no longer common in the coastal waters of Puerto Rico. Most fishes in Puerto Rico have lost the "right" to live in the coastal waters of the island. They are being pushed out by domestic or industrial pollution, uncontrolled fishing, boating, bathers or other human activities.

SPINY LOBSTER, QUEEN CONCH AND WEST INDIAN TOPSHELL RESOURCES *(Pagán-Font)*

The coastal marine invertebrates of Mona exhibit a most diversified composition. They include a large number of forms which are also found commonly in the coastal waters of mainland Puerto Rico. Because of the limitations in reproduction of these animals, it is widely agreed that such forms, especially the relatively sessile or slow moving ones, are critically susceptible to uncontrolled fishing and harvesting pressures. The future of these invertebrates is grim unless effective management techniques are put into practice.

The populations of the spiny lobster *(Panulirus argus)* or "langosta", the queen conch *(Strombus gigas)* or "carrucho", and the West Indian topshell *(Cittarium pica)* or "burgao" are important examples. For many years these invertebrates have been highly esteemed as sea food in Puerto Rico. Constantly increasing fishing has rendered their status precarious in Puerto Rico's coastal waters. This situation already applies also in some of the waters along the coast of Mona. It is feared that the affected populations may be depleted to a level from which recovery may be altogether impossible. Because of time limitations no attempts were made to conduct quantitative studies of the populations of the above invertebrates.

The information contained in this report was gathered by means of interviews with fishermen and individuals who were considered experienced parties or authorities on the three species in question. The report also includes the results of a three-day survey which was conducted during the days 2, 3 and 4 of September, 1972. Finally, the personal experiences of the author, who visited Mona for the first time in 1950, are included.

The three-day survey consisted of skin diving operations which covered the coast of Mona from Cabo Barrio Nuevo (El Capitán Cave) through El Uvero Anchorage. A total of 3 to 5 divers participated in each daily dive. Approximately, 15 hr. per diver were employed in actual diving time during the survey.

The bottom areas covered exhibited at least one of the following characteristics, or a combination of these:

1. Sand bottom
2. Rock, coral rubble and sand bottom
3. Sand bottom and *Thalassia* flats
4. *Sargasso-Turbinaria* flats plus sand bottom
5. Coral reef structures and caves.

The survey was conducted from the shoreline to a depth of up to 40 ft. The aims of the survey were (1) to perform *in situ*) observations of the populations of lobsters, conchs, and topshells, (2) to inventory these resources in a preliminary fashion, (3) to supplement interviews, earlier experiences and available literature.

Two of the divers in the group, Messrs. Germán Acosta and Luis Mendoza, for several years had fished commercially for lobsters, conchs, and topshells at Mona.

They and the author were in agreement that the populations of these invertebrates, in some areas of Mona, had been significantly reduced as compared with earlier populations found in the same areas in the fifties and sixties. The group felt that the present conditions are due to uncontrolled or unscrupulous fishing and harvesting. The group agreed also that although these populations have been markedly reduced in such areas, still they have not been as severely over-fished or affected as similar populations which dwell on the insular shelf of mainland Puerto Rico.

There exists a dire need (1) to conduct studies on the populations of the "langosta", "carrucho" and "burgao"; (2) to estimate their populations; (3) to formulate management techniques leading to rational use and conservation of these resources. The suggested study could simultaneously include these organisms in Puerto Rico, where there are already three well established fisheries of the queen conch, the spiny lobster, and the West Indian topshell. A comparative study of this sort would be extremely difficult to conduct in the coastal waters of Puerto Rico, because it would be virtually impossible to find an area free of human disturbances. In contrast, large areas of the coast of Mona remain unexposed to such disturbances. Therefore, work could be performed there with minimal or no interference from human intrusion or pollution.

A map was prepared in which areas along the coast and shelf of Mona were plotted to show the localities at which lobsters, conchs and topshells (1) used to be found; (2) are presently found (3) have never been reported. The data used in the preparation of this map came from the diving surveys and various interviews. The map includes as well the areas on Mona where sea turtles utilize as spawning sites. Instrumental in the preparation of this map were Messrs. Germán Acosta and Luis Mendoza. From the map it may be seen that the queen conch and the West Indian topshell have not been reported from Cabo Barrio Nuevo extending along the North-eastern Cape, the North Cape and ending at the Eastern Point (Punta Este). The spiny lobster has been reported from all Mona, except from the North Cape down to the East Point.

The most productive areas at present, in respect to the three invertebrates under consideration, are from Isabela Anchorage through Punta Los Ingleses. Second in importance are the Sardinera and Playa de Pájaros Anchorage. As one would expect, there seems to be a correlation between those areas which have not yet been visited frequently by humans and the areas exhibiting the largest numbers of the three invertebrates. In areas visited often by man the populations of these forms have suffered a noticeable reduction.

CONCLUSION

To end this report the members of the task force felt it appropriate to quote excerpts from an address by Mr. Harry F. Recher of the Department of Environmental Studies, The Australian Museum, Sidney, presented at a seminar in June, 1970 at Coffs Harbour by the Department of Extension, University of New England.

Mr. Rechar says: "Natural areas are important to the scientific community. They are places where basic research on the ecology and behavior of organisms can be conducted away from the "environmental noise" generated by human activities. Natural areas are invaluable aids in teaching students biology, geography, and geology.

"Scientific investigations on natural communities can yield important information for society. Man is a part of the ecosystem, and the quality of human life —indeed the very existence of man— ultimately depends on the smooth functioning of this system. To ensure a high quality environment, we must know how ecosystems work. We can do this best if we have natural areas. Studies on natural communities can be used to monitor changes in areas more directly affected by agriculture, industry, mining, fishing or intensive recreation. Knowing how natural communities function may permit us to predict long-term adverse effects, just as ecologists predicted the consequences of the indiscriminate use of persistent pesticides long before the effects of these chemicals were apparent.

"When the AEC in Australia wished to know what effects radioactive isotopes might have if released into an estuary, where they might be concentrated, and whether they would pose a threat to human health, they looked for an unpolluted estuary; unpolluted so that any effects observed would be clear and not hidden by pollution. To find an unpolluted estuary and to find one where public access could be restricted (for safety), they went to the Nadgee Nature Reserve south of Eden. If this nature reserve did not exist, if it had not been set aside 10 years ago-long before at Jervis Bay there would have been no place in New South Wales and perhaps no place in eastern Australia where this study could have been conducted. It was particularly important that public access to the area could be controlled."

These observations made by Mr. Recher may very well be applicable to Mona island. For instance, the fauna and flora of an island is usually a sample of the wildlife from adjacent land areas. Such conditions may permit studies on the communities inhabiting the Mona island realm. Subsequently, the results may be applied to similar populations dwelling in the coastal waters of Puerto Rico. The concept of "natural areas" presented by Mr. Recher is one that often governments have chosen to disregard.

Mona island is facing a critical stage in its existence. To many, Mona is just a remote, worhtless, and inaccessible island. Such ignorance, if present in the minds of government officials, could very well lead to a disastrous end of Mona. One must make certain that when speaking of Mona island that the other world of Mona, the underwater world, be given emphasis. It is hard to conceive that such a valuable resource could be overlooked as unimportant, when a decision on the future of Mona is being pondered.

It is about time that the frequently used cliché, "it is hard to justify conservation just in terms of aesthetic values," be dumped, and in its place Puerto Ricans start recognizing how the progressive destruction of environments slowly spreads through Puerto Rico and its satellite islands. It is time that present generations, young and old, balance short-term profits and material well-being against the continuous losses of resources to future generations and their material well-being. Present generations should ask, "do we have the right to destroy nature for future generations? "

This report, incomplete as it is, has led to recommendations that deserve serious consideration. Mona must be recognized as a precious and invaluable resource which present and future generations of Puerto Ricans cannot afford to lose. The members of the task force are hopeful that their efforts and dedication will not pass into historical oblivion as just another "good try", but rather as a contribution to Mona's present and future.

Let everyone make sure that in an age of uncontrolled progress, in a highly mechanized and industrialized society, in an era of space ventures and world conflicts, Puerto Ricans, by birth or adoption, find for Mona island a place of honor in Puerto Rican heritage.

Apéndice: G

The Vegetation of Mona Island

By

Roy O. Woodbury

Agricultural Experiment Station
University of Puerto Rico
Río Piedras, Puerto Rico

In spite of Mona's small size (13,658 acres), distance from a large land mass (40 miles), its lack of deep solid and its low rainfall (38 inches), it supports a known flora to date of 393 vascular plant species. Britton in 1915 published the flora of Mona Island listing 229 species. This included the unpublished collections of Stevens and others. Later (1955) Little published the trees of Mona, listing 100 species. This added 33 species, bringing the total to 262. Recent collections have added 131 more, bringing the total known species to 393, plus one unknown, thorny, shrub-like vine. Further detailed study at different seasons will undoubtedly show up other species.

Mona's flora in the most part is similar to Guánica forest plus a touch of Dominican Republic flora. The distribution pattern shows that 25 species are unique. Four are found only on Mona; sixteen have migrated west only to Mona and not beyond, and four species have migrated east to Mona and not beyond. The following lists show the species involved:

Mona and East

1. *Ficus stahlii*
2. *Pisonia albida*
3. *Portulaca caulerpoides*
4. *Chamaesyce portoricensis*
5. *Chamaesyce cowellii*
6. *Chamaesyce anegadensis*
7. *Phyllanthus polycladus*
8. *Lameriocereus hystrix*
9. *Mammillaria nivosa*
10. *Harrisia portoricensis*
11. *Forestiera rhamnifolia*
12. *Forestiera eggersiana*
13. *Cynanchium lineare*
14. *Jacquemontia cayensis*
15. *Antirhea acutata*
16. *Wedelia lanceolata*

Mona and West

1. *Pseudophoenix sargentii*
2. *Domingoa hymenodes*
3. *Sarcomphalus taylorii*
4. *Ipomoea microdactylon*

Mona Only

1. *Epidendrum brittonianum*
2. *Chamaesyce monensis*
3. *Cynanchium monense*
4. *Eupatorium oteroi*

Besides the above 25 species one could add 17 more (or approximately 11 per cent of the flora) which are either rare or endangered.

The above distribution pattern shows that most of Mona's species have a wide range but some have a very narrow and peculiar distribution, such as *Harrisia* which was once found in the Ponce area but has not been seen there recently. So for all purposes it is now endemic to Mona. Another cactus, *Mammillaria nivosa* has a very peculiar distribution pattern, from Mona to Tortola and skipping the big island of Puerto Rico.

For convenience Mona's vegetative cover can be divided into the following six types:

Uplands	Acres
1. Bare or low cactus growth (near clifffs)	250
2. Shrubby (N.E. and E. sides)	1,950
3. Low forest (dry)	10,130
4. Forest (sinkholes)	420
Lowlands	
5. Tall forest (moist)	790
6. Other	120
Total	13,660

As some of the rare and endangered species are located in each of the above habitats, it would be advisable to set aside or preserve at least some of everyone.

Apéndice: H

Mona Island Terrestrial Crustaceans

By

Donald S. Erdman

Puerto Rico Department of Natural Resources

Mona Island is in effect an isolated oceanic island with deep water all around it except for a small shallow shelf. Up to the present time, it is believed that human beings have had a minimum impact on terrestrial crustacea at Mona Island in contrast to mainland Puerto Rico where hermit crabs and land crabs *(Cardisoma)* have been greatly reduced in numbers.

A brief mention is made of strictly marine crustacea because of special human interest. Spiny lobster *Panulirus argus* occur under rock and corals close to shore. While not abundant they are apt to be large in size, 2-3 lbs. The coral crab *Carpilius corallinus* or "juey dormido" is a red edible crab up to one pound in weight which can be caught in fish pots on the 10 fathom sand bank west of Sardinera.

In accord with the ecological classification of Chace and Hobbs (1969) pp. 33-34, the crustaceans are discussed as follows:

1. Typically marine species
   a. *Grapsus grapsus* are flat crabs with long legs which climb rocks out of water on occasion near shore.
   b. *Sesarma ricordi* are fast moving small crabs found under beach debris. On June 4, 1971 a number of juvenile crabs about 3 mm. in carapace length were found running around the walls of one of the concrete cottages near the beach; 4 young crabs were preserved.

2. Subterranean species
   Typhlata monae Chace, (1954) is a fresh water cave shrimp described from a well near Sardinera Beach.

3. Typically terrestrial species that have marine larvae
   A. Living in snail shells: *Coenobita clypeatus,* "cobo" or land hermit crab
   B. Burrowing on sand beaches: *Ocypode quadrata,* ghost crab.
   C. Burrowing in coastal or subcoastal areas: *Gecarcinus ruricola* and *G. lateralis*

Mattox (1950) has reported on a species of fairy shrimp from temporary rain pools on the top of the Cliff road ("Hell Road") from Pájaro Beach to Uvero. Some about the size of brine shrimps were seen by the author in such a rainwater pool along Hell road in March 1960; and there have been several reports during the summer of 1972.

Of particular interest are the locally known spawning migrations of the land hermit crab *Coenobita clypeatus.* Apparently these migrations occur in restricted areas at certain times in summer and in connection with a moon phase.

Provenzano (1962) studied the larval development of *Coenobita* and spawned several females in aquaria in August 1960 and 1961 at the time of the new moon phase. He raised one larva to nearly the juvenile crab stage in 57 days.

At Mona Island, however, hermit crabs with embryos in their eggs or actually spawning have been found in August at the time of the first quarter moon phase on the following dates for three years: August 14, 1964; August 1, 1971 and August 15, 16 and 17, 1972.

A large migration of an estimated 10,000 hermit crabs was observed just north of Sardinera concrete dock on August 16 and 17; another migration was observed at Uvero Beach on August 15.

The land hermit crab is good bait for catching fishes, and the species should be protected against extensive depletion. On the evening of August 15, 2,200 crabs were marked with bright red paint to trace their migrations. On August 19, one crab had climbed the ridge and was north of the radio tower near Barrio Nuevo.

The land crab, *Gecarinus ruricola,* is being harvested to an unknown extent and may be less abundant at present than formerly. A female was found on August 17 with the hermit crabs in shallow water. Her abdomen was pulsating and the crab was presumably spawning.

The scarcity of the true land crab or "juey" *Cardisoma* at Mona Island may be due to the lack of a favorable land environment for this species.

One *G. lateralis* about 1" in carapace length occured with the hermit crabs on land on the evening of August 16.

The apparent lack of fiddler crabs, *Uca* spp. at Mona Island may also be due to the lack of favorable environmental conditions.

Other terrestrial species of crustaceans occur on Mona Island, but they are less well known than the aforementioned species.

RECOMMENDATIONS

It is recommended that the hermit crab migrations be protected from large scale commercial exploitation since this natural renewable resource forms a good natural bait supply for fishermen.

It is recommended that the land crabs on the island be studied in greater detail to determine what rate of harvest is allowable without greatly reducing the numbers of these crabs.

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Apendice: I

The Terrestrial Arthropoda (Exclusive of Insecta and Crustacea) of Mona Island, Puerto Rico

By

Manuel J. Vélez Jr.
Biology Department
University of Puerto Rico
Río Piedras, Puerto Rico

INTRODUCTION

The terrestrial arthropod fauna of Mona Island is comprised for the most part by members of the Classes Insecta, Chilopoda (centipedes), Arachnoidea (spiders, scorpions, etc.) and Crustacea. No species of millipeds (class Diplopoda), another important arthropod group, has even been reported or found on the Island on any of our trips or in collections made by other biologists.

The Classes Insecta and Crustacea will be dealt with in separate reports of the "Mona Island Study" by Dr. Luis F. Martorell and Mr. Donald S. Erdman, respectively. Consequently, the present report is concerned mainly with the remaining group of arthropods (spiders, scorpions and centipedes).

The present work is based mostly on collections and field studies that were made during the months of March (23-26) and August (8-12) of 1972. Collections and field studies of previous work carried out by the author and other collaborators (Dr. Harold Heatwole and the late Prof. Francis Rolle) have also been included.

I wish to express my sincere gratitude and appreciation, for the great help offered in identifying the specimens, to my graduate students at the University of Puerto Rico, Elba Santiago and Raúl Pérez, who are at present specializing in centipedes and spiders, respectively.

THE SPIDERS

The spider fauna of Mona Island is relatively well known, although, as it has been evidenced by new records reported in the present work, additional field work should disclose new records and species. In 1915, Lutz listed for the first time all the species of spiders that were known from the Island. The number of species was increased to 21 with Petrunkevitch's work (1929, 1930), "The Spiders of Porto Rico." More recently, Bryant (1947), working with additional material collected on Mona by Dr. Jorge J. Serrallés (April, 1944) and Mr. Harry Beatty (August, 1944), described four new forms and listed a total of 41 species for the Island. Bryant (1947) apparently missed some of the previous records (at least six from Petrunkevitch's work alone) since the total number at that time should have been 49 species.

The following checklist includes all 49 species of spiders that had been reported for Mona Island to the present. To this list, we must now add the following three new records: (1) a species of *Ischnocolus* which might prove to be new and which is the first record for the entire tarantulan Suborder Mygalomorphae, (2) *Selenops linbourgi* and (3) *Scytodes fusca.* This brings the total number of species of spiders now known from Mona to 52. Most of these forms have been described adequately in the literature cited, and consequently no attempt is made here to redescribe them.

SPIDERS PREVIOUSLY REPORTED

Class Aranae

Order Labidognatha

Division Cribellata

Family Oecobiidae

1. *Oecobiius benneri* Petrunkevitch, 1929

*2. *Oecobiius parietalis* Hentz,

Note: Banks listed this species from Mona Island but Petrunkevitch felt it was misidentified and that O. parietalis was not present in the West Indies.

Family Filistatidae

3. *Filistata hibernalis* Hentz, 1842

Division Acribellata

Family Oxyopidae

4. Peucetia viridans (Hentz, 1845)

5. Oxyopes salticus Hentz, 1845

6. Oxyopedon rana Simon, 1891

7. Hamataliwa haytiana (Chamberlin, 1925)

Family Pholcidae

8. Physocyclus globosus (Taczanowski, 1873)

Family Theridiidae

Subfamily Latrodectinae

9. Latiodectus mactans (Fabricius, 1775)

Subfamily Argyrondinae

10. Anelosimus studiosum (Hentz, 1850)

11. Conopistha argyroides (Walckenaer,)

**12. Conopistha nephilae* Taczanowski, 1873

13. Theridion insulicola Bryant, 1947

Family Argiopidae

Subfamily Gasteracanthinae

14. Gasteraicantha cancriformes (Linnaeus, 1767)

Subfamily Araneinae

**15. Metepeira labyrinthea* (Hentz, 1847)

16. Metepeira virginensis Chamberlin and Ivie,

17. *Neoscona volucripes* (Keyserling, 1863)
*18. *Neoscona oaxancensis* (Keyserling, 1863)
19. *Cyclosa caroli* (Hentz, 1850)
20. *Wixia serrallesi* Bryant, 1947
21. *Eriophora edax* (Blackwell, 1863)
22. *Parawixia cambridgei* Bryant, 1940
23. *Edricus crassicauda* (Keyserling, 1965)
24. *Eustala anastera* (Walkenaer, 1837)
25. *Aranea displicata* (Hentz,)

Subfamily Argiopinae
26. *Argiope argentata* Fabricius, 1775
27. *Argiope trifasciata* Forskal, 1775

Subfamily Nephilinae
28. *Nephila clavipes* (Linnaeus, 1758)

Subfamily Tetragnathinae
*29. *Leucage venusta* (Walckenaer, 1837)
30. *Leucage regni* (Simon, 1897)
31. *Plesiometa argyra* (Walckenaer, 1837)

Family Sparassidae

Subfamily Heteropodinae
32. *Heteropoda venatoria* (Linnaeus, 1767)

Subfamily Mocrommatinae
33. *Olios bicolor* Banks, 1914

Subfamily Sparianthinae
34. *Stassina macleayi* Bryant, 1940

Family Selenopidae
35. *Selenops insularis* Keyserling 1881

Family Thomisidae

Subfamily Misumeninae
36. *Misumenops celer* (Hentz, 1847)
37. *Misumenops asperatus* (Hentz, 1847)

Family Clubionidae

Subfamily clubioninae
38. *Chiracanthium inclusum* (Hentz, 1847)

Subfamily Anyphaeninae

39. Aysha tenuis (Koch, 1866)

40. Wulfila immaculata Banks, 1914

Family Salticidae

41. Stoides placida Bryant, 1947

Subfamily Pelleninae

42. Habrognathus translatus (Peckham, 1901)

Subfamily Dedryphantinae

43. Hentzia squamata (Petrunkevitch, 1930)

**44. Hentzia vernalis* (Peckham, 1893 ?)

45. Sidusa mona Bryant, 1947

Subfamily Hasariinae

46. Siloca minuta Petrunkevitch, 1930

**47. Siloca monae* Petrunkevitch, 1930

Family Ctenidae

48. Oligoctenus ottleyi Petrunkevitch, 1930

Family Loxoscelidae

**49. Loxosceles caribbaea* Gertsch, 1958

**Note: Species marked with an asterisk were not reported by Bryant (1947).*

DISTRIBUTION AND ABUNDANCE OF SPIDERS

From the point of view of animal distribution (terrestrial or inland) Mona Island can be divided into the following general ecosystems: (1) rocky shores, (2) sandy beaches, (3) coastal plains (terrace), (4) bajuras (sinkholes), (5) caves, (6) limestone tableland and, (7) temporary pools and water reservoirs.

The coastal plains are by far the most important ecosystem for spiders as well as for many other terrestrial invertebrates on Mona Island. It is here that we find the greatest number of species and individuals. The most common species on the Island is the neotropical Golden Silk spider, *Nephila clavipes.* This large and colorful form, with hairy legs, is most abundant in the coastal plains. In some places the populations may consist of one to two individuals per two square meters. The second most common form is another neotropical spider *Gasteracantha cancriformes.* This is a small black and white spider with a six-spined abdomen. Other common species of the coastal plains found in similar situations include: the neotropical *Argyope argentata, Leucage venusta, L. regni,* and *Argyrodes nephilae.* All six species mentioned above make webs on branches of trees at relatively low altitudes (3-10 feet). There are under the bark of trees, especially *Casuarina equisetifolia,* several dorsa-

ventrally flattened spiders with extremely long legs. The most common forms here are *Selenops lindbourgi, Wala squamata, Scytodes fusca,* and *Siloca monae.* On the rocky ledges bordering the plains, around Sardinera and Uvero, one finds in small holes larger species like *Filistata hibernalis, Loxosceles caribbaea,* and *Ischnocolus* sp.

The fauna of the "bajuras" or sinkholes (Bajura de los Cerezos and El Corral) seemed extremely poor in spiders, but not in other groups of invertebrates (centipedes, scorpions, etc.). Although we were not able to collect any spiders in the "bajuras", some fast moving flattened forms like *Wala* and *Selenops* were seen under the bark of trees. Very irregular spider webs of an unidentified species were also very common in the distal branches of the trees in this area. But all efforts made to collect specimens were in vain.

No spiders were collected inside any of the caves. Some spider species typical of the coastal plains are found, however, near the entrances.

The spider fauna of the limestone tableland is also very poor. Occasionally present in this area are spiders from the coastal plains, especially *Argyope argentata* and Nephila clavipes. It is felt, nevertheless, that more intensive collecting on the limestone tableland should disclose species adapted to this habitat.

THE SCORPIONS

No species of scorpions have previously been reported from Mona Island. During the present study three species were secured, representing three genera and two families as follows:

Order Scorpionida
- Family Diplocentridae
  1. *Diplocentrus scaber* Pocock, 1894
- Family Buthidae
  2. *Isometrus maculatus* (De Greer, 1778)
  3. *Centruroides insulanus* Thorel, 1876

Diplocentrus scaber is by far the most common and smallest species of scorpion on Mona. This form is generally found under the leaf litter or stones from the coastal plains to the limestone tableland and the "bajuras" (Bajura de los Cerezos). The species is also present in Puerto Rico where it is restricted to a small xerophytic region of the south-western coast (Guánica). It can be readily recognized by its small size (less than three-fourths of an inch in length), pectines with eight teeth and very stout tail.

Another form, *Isometrus maculatus,* was represented by only one specimen in the University of Puerto Rico Museum of Biology Collections. Unfortunately it does not have specific data as to locality and habitat. The species ohad not been collected in any of our trips to the Island. *Isometrus maculatus* has a cosmotropical distribution, having being reported previously from Puerto Rico where it seems to be extremely rare. The species can be easily distinguished from other local forms by the light yel-

lowish coloration, delicate body, and very slender tail, which bears a prominent subaculear spine.

Centruroides insulanus is the largest and most conspicuous scorpion of all three forms. The species is quite common under the bark of trees, from the coastal plains to the limestone tableland. Females were found carrying 20-22 juveniles during the month of August (1972). *Centruroides insulanus* can be distinguished from all other local forms by three pale longitudinal lines along the dorsum, the darker coloration, and the heavier and stouter body and tail. The species had been previously reported for Jamaica.

THE TAILLESS WHIPSCORPIONS

No tailless whipscorpions or "Guavás" as they are known in Puerto Rico, have been previously reported from Mona Island and no specimens were collected in any of our trips there. However, in March 23, 1972, a fairly complete molt of a small guavá was secured from the rocky ledge near Sardinera. The fragile molt was broken with the movement of the preserving fluid in the jar and it was therefore impossible to identify it. A very thorough search for guavás in the rocky ledges near Sardinera was effected during our last trip in August 1972 but did not yield any specimens or molts. The species most probably belongs to the Family Phrynidae which is represented in Puerto Rico by the large cave guard *Phynus palmatus.*

THE CENTIPEDES

No centipedes had been previously recorded for Mona Island. Collections made during the last few years reveal that at least four species are present on the Island, representing two orders, four families and four genera as follows:

Class Chilopoda
- Order Scolopendromorpha
  - Family Scolopendridae
    1. *Scolopendra alternans* Leach, 1814
  - Family Otostigmidae
    2. *Otostigmus caraibicus* Kraepelin, 1902
  - Family Cryptopidae
    3. *Newportia* sp.
- Order Geophilomorpha
  - Family Oryidae
    4. *Notiphilides erga* Chamberlin, 1950

The largest and most conspicuous of these centipedes is *Scolopendra alternans.* It has a wide distribution throughout the West Indies from the Bahamas and Cuba to Tobago, including Puerto Rico. On Mona the species appears to be restricted to the

coastal plains from Sardinera and Uvero to Playa de Pájaros, but occasional individuals were found at Bajura de los Cerezos. In all these areas they are generally under stones or dead logs. The individuals of *Scolopendra alternans* from the Mona Island populations are smaller than those from Puerto Rico and have also a distinctive coloration pattern. At present it is felt, however, that these differences alone are not sufficient to warrant a different classification, although it is obvious that these isolated Mona Island populations are distinctive and should be studied more thoroughly.

A second species of centipede, *Notiphilides erga,* is usually present in great numbers under the bark of trees (especially *Casuarina equisetifolia)* on the coastal plains (Sardinera and Uvero). This species is easily distinguished by the very long (2-3 inches) and slender (less than 1/8 inch) body, pale yellowish coloration, and the great number of legs (over 100 pairs). Several females of this form were found carrying eggs (about 15) and juveniles (10-14 young) during August 8-12, 1972. *Notiphilides erga* is also common in Puerto Rico and Culebra, but not on the other islands.

Another common form having a much wider distribution on Mona is *Otostigmus caraibicus.* This small (about one inch) and yellowish species, with blue legs, is frequently found throughout the Island from the coastal plain to the limestone tableland where it may be present under rocks and leaf litter. The species is also found in Puerto Rico.

The fourth form of centipede secured from Mona probably represents a new species of the Genus *Newportia.* Some representatives of this genus have been reported from Puerto Rico.

THE ABSENCE OF MILLIPEDS

The absence of millipeds from Mona is to some extent understandable. The Island lacks for the most part an adequate soil cover with humus and leaf litter, in addition to the prevalent low humidity and rainfall. These conditions and the great distance from Mona to other islands like Puerto Rico and Hispaniola would make it very difficult for a colonizing species to reach Mona and establish itself successfully on that Island. Even such hardy cosmotropical species as *Trigoniulus lumbricinus and Orthocricus monilicornis,* common in very small and dry islands like Culebra and St. Thomas, have not become established on Mona or Desecheo Islands.

THE IMPORTANCE OF THE FAUNA DISCUSSED

The relative importance of the arthropod fauna of an isolated Island such as Mona can be seen in several different ways.

First of all, of course, the arthropods, as well as any other invertebrate groups, have very definite roles in nature. The maintenance of a well balanced ecosystem is probably their most important role. This balance of nature is still more crucial in smaller and delicate ecosystems such as those present in small islands like Mona. More than 50 per cent of the fauna that has become extinct in the last few decades

was from small islands. From the point of view of the economics, such a fauna can not be assessed or measured accurately or even relatively in terms of productivity. Yet from our knowledge of these phenomena of nature, in general, we can be sure that there are many of those animals (for example reptiles, birds) that depend on arthropods as a food source (entirely or partially), and that these in turn are probably responsible themselves for maintaining well balanced populations of their own species as well as of other species present there.

Excluding insects (wasps, bees, etc.) there are in Mona only four species of arthropods that are poisonous to man. Although all spiders are poisonous to a certain extent, one species from Mona, the black widow spider *(Latrodectus muclans)*, is potentially dangerous to man, and these are very scarce. The only centipede capable of biting man, mainly because of its large size, is *Scolopendra alternans.* The bite is generally not serious. The two larger scorpions, *Isometrus maculatus* and *Centruroides insulanus* generally produce a very mild sting. However, the secretive habits of all of these forms, under logs, stones and the bark of trees, make it unlikely that they would on their own encounter a human being.

From the purely scientific point of view many of the arthropods of Mona are of great importance because they provide unique opportunities for studies of isolating mechanisms and speciation, population genetics and dynamics, zoogeography, historical geology, and biosystematics in general. The key to these studies is the relative isolation of Mona, distance from other islands, the larger number of endemic species (snails 33 per cent; reptiles, 70 per cent; spiders, 20 per cent) and even the non-endemics which have been isolated for many hundreds of years.

Nearly one fifth (18 per cent) of the spiders appears at present to be endemic to Mona Island, while 50 per cent (including the 18 per cent) autochthonous to the West Indies. This degree of endemicity is relatively low (as should be expected for a group like spiders) when compared to that of terrestrial mollusks (33 per cent) or reptiles and amphibians (70 per cent).

Most of the non-endemic spiders of the West Indies are also present in South, Central, and North America. Very few forms (see table on Distribution of Spiders) are common to Mona and Puerto or to Mona and Hispaniola, exclusively. Detailed studies of the geographical distribution and relationships of the species and genera of spiders and other groups, using numerical analysis and other modern approaches to this problem, should reveal more clearly the affinities of the fauna of Mona to the other West Indian Islands, and to the Continents. With the information that we have at present we can make only preliminary statements as to the origin of the Mona Island spider fauna.

As stated above, nearly one fifth of the spiders of Mona are endemic to that Island. Most of these appear to have been derived from species that are represented by several genera on other West Indian Islands. Many of these endemic forms seem to be more directly related to Puerto Rico and Hispaniola than to the other islands. Thus, most of the spiders of Mona seem to have arrived from two directions, from the East thru Puerto Rico, and from the West thru Hispaniola. Many of the remaining forms are either cosmotropical or neotropical, with the exception of several species that are common exclusively (See table on Geographical Distribution)

to the West Indies and to North or Central America. So, it is possible that as is the case with other groups of animals the fauna has more affinities with Central America, and that the North American element came thru Central America.

General Distribution of the Mona Island Spiders

Endemic to Mona: *Ischnocolus sp., Theridion insulicola, Neoscona volucripes, Wixia serrallesi, Aranea displicata, Stoides placida, Hentzia squamata, Siloca monae, Metepeira virginensis*

Puerto Rican Region (Mona, P.R. and Virgin Islands) *Selenops linbourgi, Oligoctenus ottleyi*

Mona Island and Hispaniola: *Anclosimus studiosum*

Greater Antilles: *Oecobius benneri, Hamataliwa haytiana*

West Indies (Lesser and Greater Antilles): *Oxyopedon rana, Conopistha argyroides, Parawixia cambridgei, Leucage regni, Olios bicolor, Stassina maclegayi, Selenops insularis, Habrognathus translatus, Loxosceles caribbaea*

West Indies and South America: None reported

West Indies and Central America: *Aysha tenuis*

West Indies and North America: *Heteropoda venatoria*

West Indies, South, and Central America: *Edricus crassicauda*

West Indies, South, and North America: *Conopistha nephilac*

West Indies, Central, and North America: *Filstata hibernalis, Peucetia viridans, Neoscoma oaxancensis, Misumenops celer, M. asperatus, Chiracanthium inclusum*

West Indies, South, Central, and North America: *Oxyopes salticus, Physocyclus globosus, Latrodectus mactans, Gasteracantha cancriformes, Metepeira labyrinthea, Cyclosa caroli, Eriophora edax, Eustala anastera, Leucage venusta, Plesiometa argyra, Scytodes fusca, Argyope argentata, Nephila clavipes, Argiope trifasciata* (cosmotropical)

Geographical Distribution of the Spiders of Mona Island

	S.A.	L.A.	V.I.	P.R.	Des.	Mona	Hisp.	Cuba	Jam.	C.A.	N.A.
1. Ischnocolus sp.						*					
2. Oecobius benneri			*	*		*	*	*			
3. Filistata hibernalis			*	*		*	*	*		*	*
4. Peucetia viridans				*		*	*	*	*	*	*
5. Osyopes salticus	*	*	*	*		*	*	*	*	*	*
6. Osyopedon rana		*		*		*		*			
7. Hamataliwa haytiana				*		*	*				
8. Physocyclus globosus	*	*	*	*		*	*	*	*	*	*
9. Anelosimus studiosum	*			*		*	*	*	*	*	*
10. Latrodectus nactans						*	*				*
11. Conopistha arguroides						*		*			
12. Conopistha nephilae	*		*	*	*	*	*	*			*
13. Theridion insulicola						*					
14. Gasteracantha cancrifomis	*			*		*		*	*	*	*
15. Metepeira labyrinthea	*	*	*	*	*	*		*		*	*
16. Metepeira virginensis						*					
17. Neoscoma volucripes						*					
18. Neoscoma oaxancensis		*		*		*		*		*	*
19. Cyclosa caroli	*	*		*		*		*		*	*
20. Wixia serrallesi						*					
21. Parawixia cambridgei						*		*			
22. Eriophora edax	*		*	*		*	*	*	*	*	*
23. Edricus crassicauda	*			*		*		*		*	
24. Eustala anastera	*		*	*		*		*		*	*
25. Aranea displicata						*					
26. Argiope argentata	*		*	*	*	*		*		*	*
27. Argiope trifasciata	*		*	*	*	*		*		*	*
28. Nephila clavipes	*		*	*		*	*	*	*	*	*
29. Leucage venusta	*	*		*		*		*	*	*	*
30. Leucage regni		*	*	*		*		*	*		
31. Plesiometa argira	*	*	*	*		*			*	*	*
32. Heteropoda venatoria			*	*		*	*	*			*

Geographical Distribution of the Spiders of Mona Island (Continued)

33. Olios bicolor				*	*	*		*			
34. Stassina macleayi						*		*			
35. Selenops insularis				*		*	*	*			
36. Selenops linbourgi			*	*		*					
37. Misumenops celer				*		*	*	*		*	*
38. Misumenops asperatus		*		*		*	*	*		*	*
39. Chiracanthium inclusum		*		*		*	*	*		*	*
40. Ausha tenuis		*		*	*	*	*	*		*	
41. Wulfila immaoulata				*		*		*			
42. Stoides placida						*					
43. Habrognathus translatus				*		*		*	*		
44. Hentzia squamata						*					
45. Hentzia vernalis		*		*	*	*	*	*			
46. Sidusa mona						*					
47. Siloca minuta						*					
48. Siloca monae						*					
49. Oligoctehus otleyi				*		*					
50. Loxosceles rukibbaea			*	*		*	*		*		
51. Scytodes fusca	*	*	*	*		*	*	*	*	*	*

S.A. - South America
L.A. - Lesser Antilles
V.I. - Virgin Islands
P.R. - Puerto Rico
Des. - Desecheo
Hisp. - Hispaniola
Cuba - Cuba
Jam. - Jamaica
C.A. - Central America
N.A. - North America

GENERAL RECOMMENDATIONS

Before making recommendations, the one thing that should be stressed once more is the uniqueness of Mona, its fauna and its importance in the studies of many problems in biology (evolution, speciation, isolation, etc.), history, archaeology and geology of the Caribbean Region. Every effort should be made to preserve the existing species on the Island. It is felt that, besides taking the usual measures to protect the fauna, the most important thing is to protect the most valuable habitats from destruction.

Even though in the past the coastal plains have been the most disturbed by the agricultural practices of the scant populations (Indians and post Colombian settlers) that have lived there, they are still extremely valuable because they probably have the largest number of endemic animal species and individuals (terrestrial molluscs, arthropods, reptiles, and amphibians). It seems to me that today the most vulnerable ecosystems are those of the coastal plains since it is there that most people that go to Mona spend most of their time and where the government has established housing facilities for visitors. Because of this whole situation, studies should be carried out to determine the most valuable habitats and areas of the coastal plains that could be established as sanctuaries protected from littering, destruction or any other kinds of disturbances that could endanger the endemic species. Special recreational areas could also be established (for example Sardinera and Uvero) where a limited number of people (probably not more than 25 at any one particular place) could stay.

Similar studies should be made of some of the most accessible caves in order to determine those which are more valuable from an archaeological, historical, geological, or biological (fossil remains) point of view. Caves of great importance should be protected from the vandalism that is already occurring in some of them (paintings over indian signs on the walls). A few of these valuable caves are already known to archaeologists and geologists. Those caves with little scientific value could then be used for recreational purposes.

The bajuras or sinkholes also constitute very unique ecosystems that should be preserved. The Indian "ballparks" or ceremonial plazas found in some of the bajuras should be protected and cleared of trees and other vegetation, but only along the lines of stones that delineate the park. Clearance of the whole area covered by the parks could be unwise. The clearance would not only destroy most of the ecosystem of these sinkholes but would also aggravate erosion and could eventually ruin the park itself.

Great destruction or damage to the limestone tableland communities is not foreseen in the near future or at least is something difficult to conceive due to the nature of the terrain and the vegetation, unless large scale construction projects are developed. Nevertheless botanists and terrestrial ecologists should point out if there are any singular or unique plant community that ought to be particularly protected. If there are, adequate measurements should be taken to insure that they are preserved.

Time moves rapidly, this last paragraph was written 24 hours ago. Now 24 hours after it was written, I have been told by some of our students that just came back from Mona, that large areas of the limestone tableland are being cleared by burning of the vegetation.

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Apéndice: J

The Insects of Mona Island, P.R.

By

Luis F. Martorell
Department of Entomology
Agricultural Experiment Station
University of Puerto Rico
Río Piedras, Puerto Rico

The insects of Mona Island have been fairly well studied, the latest publication on this subject being written by Ramos as published in the Journal of Agriculture of the University of Puerto Rico in 1946. Based on his paper this report is hereby presented.

Mona Island has been the center of attraction for biological studies by many scientists since the beginning of this century. This report would not be complete without a historical account of these men of science which in one time or another visited the Island in search of information.

SCIENTIFIC EXPLORATION

Ramos, gives a very interesting historical summary of the scientific activities in Mona. From the pages of his publication the following is cited:

"The earliest published records of insects from Mona Island appear to be those of the elaterid *Adelocera rubida* Schwarz and of the phasmid *lampomius bocki* Brunner and Redtenbacher, described from the Island in 1902 and 1908 respectively. Since a German concern was engaged for several years, from the end of the last century to the beginning of the present one, in removing guano from Mona Island, it appears probable that the material from which these two species were described was secured by some member of the German personnel of that concern, who sent it to museums in his homeland.

"Mr. E.G. Smyth and Mr. R.H. Van Zwaluwenburg appear to have been the first entomologists to visit the Island and collect insects there, going by sailboat from Mayagüez in December 1913. The few records of insects collected by Smyth at that time on Mona are listed in the accession catalogue of the Agricultural Experiment Station of the University of Puerto Rico at Río Piedras under the numbers 1300 to 1399 in 1913.

"Until 1914 when the explorations for the Scientific Survey of Porto Rico and the Virgin Islands, under the combined auspices of the New York Academy of Sciences, the American Museum of Natural History, and the University of Puerto Rico were initiated, Mona Island was practically unknown and unexplored entomologically. During February 21-26 of that year, a small party of scientists visited the Island for the purpose of exploring it and collecting plants and animals. Dr. Frank E. Lutz, of the American Museum of Natural History, was among the members of that party. During the 5 days he spent on the Island he collected rather intensively, contributing much to our present knowledge of the insect fauna of Mona. Many of the new species of insects that have been described from the Island were secured by him on that occasion.

"In April 1935 the writer accompanied the late Dr. Stuart T. Danforth on a 3-day trip to Mona Island, primarily for the purpose of studying and collecting birds. A small collection of insects made by him on that occasion is reported in this paper for the first time.

"Mr. Francisco Seín, Jr. was on Mona Island in August 1926, and Dr. George N. Wolcott visited it by airplane on January 24, 1940, to advise regarding an extensive outbreak of thrips on onions on the coastal plain.

"The writer obtained determinations of insects collected on Mona in March 1937, by Mr. H.A. Pérez of the Insular Forest Service. On August 4-7, 1939 and March 29-April 4, 1940, he collected intensively there, adding much information about insects in the Island. He is responsible for many of the records from Mona in the accession catalogue of the Agricultural Experiment Station of the University of Puerto Rico for the years 1939 and 1940 as reported by Wolcott 1941[4].

"Professor Virgilio Biaggi, Jr., of the Biology Department, College of Agriculture and Mechanic Arts of the University of Puerto Rico, was on an expedition from the Institute of Tropical Agriculture of Mayagüez, Puerto Rico, that visited Mona Island during March 2-7, 1944 for the purpose of collecting plants and animals. Although he was engaged primarily in collecting birds, reptiles, and amphibians, Professor Biaggi was able to make a small collection of insects for the writer during his visit.

"On April 1-7, 1944 Dr. George N. Wolcott, Mr. Jorge Serrallés, of the Agricultural Experiment Station of the University of Puerto Rico, and the writer visited the Island and collected intensively along the western and southwestern coastal plains and at several places on the plateau.

"During the summer of the same year, several persons visited Mona and kindly collected insects for the writer, thus adding many species new to his Mona Island collection and much additional data about the island's entomological fauna. They were Messrs. Enrique Huyke and Antonio Ferrer Monge of Mayagüez, Puerto Rico, who spent several days on the island during the latter part of June and July respectively, and Mr. Harry A. Beatty of St. Croix, Virgin Islands, who stayed in the island from August 11 to August 31 and who collected at Sardinera and Uvero Beaches and over the plateau."

Since then, sporadic trips have been made to the Island by the scientific personnel of the Agricultural Experiment Station of the University of Puerto Rico, among these, Dr. Luis F. Martorell and José G. García-Tuduri, with the main interest in studying the termite fauna of Mona as well as of Desecheo Island. The last of these trips was made in December 1972.

THE RECORD

Ramos, in his paper presents a total of 526 species of insects recorded from Mona Island. Of this number, 24 species, or 4.6 per cent, are endemic to the island; 27 species, or 5.1, are also known only from the Puerto Rico mainland; 53 species, or 10.1 per cent, although known from other West Indian islands or other regions, are not known from Puerto Rico itself; and 422 species, or 80.2 per cent, are widely ranging forms, occurring in some or in all of the West Indies, or in neighboring regions. (See Table 1).

The Coleoptera are represented by 123 species of which 5 are endemic, 7 occur also only in Puerto Rico itself, and 16 are not known from the latter island, although they occur also in other West Indies.

The Diptera include 78 representatives. Of these, 6 species are endemic to Mona Island, 6 occur also only in Puerto Rico, and 7 range throughout other West Indian islands but not in Puerto Rico itself.

The Hymenoptera are represented by 65 species, of which 2 are endemic, 3 are shared with Puerto Rico only and 10 occur in other of the West Indies but not in Puerto Rico itself.

Table 1

Order	*No. of families*	*Endemic species*	*In common with P.R.*	*Not known from P.R.*	*Of wide distri-bution*	*Total*
1. Thysanura	1	0	0	0	1	1
2. Collembola	1	0	0	1	0	1
3. Orthoptera	8	3	1	0	24	28
4. Dermaptera	1	0	0	0	1	1
5. Isoptera	1	1	1	1	1	4
6. Neuroptera	3	0	1	3	4	8
7. Odonata	2	0	0	0	5	5
8. Mallophaga	1	0	0	0	1	1
9. Thysanoptera	1	0	0	0	1	1
10. Homoptera	16	3	2	2	56	63
11. Hemiptera	16	3	1	4	49	57
12. Coleoptera	36	5	7	16	95	123
13. Lepidoptera	20	1	5	9	73	88
14. Diptera	22	6	6	7	59	78
15. Siphonaptera	2	0	0	0	2	2
16. Hymenoptera	21	2	3	10	50	65
Totals	152	24	27	53	422	526
Percentage		4.56	5.11	10.07	80.22	

In the Homoptera, 63 species are recorded from the island of which 3 are endemic, 2 occur also in Puerto Rico only and 2 are known from Puerto Rico itself although they occur in other localities. The family Kinnaridae, until recently not known from Puerto Rico itself, is represented in Mona by a new genus and species.

The Hemiptera is represented by 57 species of which 3 are endemic, one is shared with Puerto Rico only, and 4 do not occur in the latter island itself.

A total of 88 species is recorded in the Lepidoptera. Of these, one new species is described from the island, 5 are shared with Puerto Rico only and 9 with other regions but not Puerto Rico itself.

The Orthoptera are represented by 28 species, of which 3 are endemic forms, one is shared with Puerto Rico only, and the rest are widely distributed in the West Indies.

Of the remaining orders of insects represented, the Isoptera is the only one having an endemic species from the Island.

The paucity of the insect fauna of Mona Island, as shown by the above analysis, is probably due not only to the small area of the island but also to its extreme aridity and scant vegetation. Its most interesting feature is undoubtedly the fact that the number of species in common with other regions but not known from Puerto Rico itself (53 species, or 10.7 per cent) is nearly two times greater than the number of species in common with that island (27 species, or 5.11 per cent). This could be interpreted in the sense that the island's insect fauna has less affinities with that of Puerto Rico itself than with that of the other Greater Antilles. Unfortunately, lack of knowledge of the insect faunas of these islands, especially Hispaniola, does not permit a more definite statement in this respect.

SUMMARY

A total of 526 insect species representing 16 orders and 152 families have been so far recorded from Mona Island, with notes on their distribution, abundance and host plants. Included in the number of these already known species are the new ones described by Ramos in his 1946 paper.

These species are: *Paradarnoides danforthi* Ramos, a membracid; *Paraprosotropis monensis* Ramos, a kinnarid; *Flatoidinus pseudopunctatus* Ramos, a flatid; *Ozophora octomaculata* Ramos, a lygaeid and the geometrid moth described by Dr. W.T.M. Forbes of Cornell University, *Ptychpoda monata* Forbes.

Of special interest is the notable absence of arboreal termites. In Puerto Rico and nearby islands two species are common, namely *Nasutitermes costalis* and *N. nigriceps,* both of the Family Termitidae. Yet in Mona there are no representatives of the modern family Termitidae. The place is occupied by four different species of termite of the primitive family Kalotermitidae, with one interesting species, *Kalotermes mona* Banks, endemic to the Island.

The coreid bug, *Sphictyrtus whitei* Guérin Méneville, is extremely abundant in Mona, yet not recorded from Puerto Rico or Santo Domingo. It is however, known from Cuba, where it was described in 1857 and also has been recorded from San Salvador in the Bahamas.

RECOMMENDATIONS

Mona Island has a much larger number of insect species, comparatively speaking, than Puerto Rico, if one considers its very small size of approximately 6 miles square. The number of endemic species, 24 (4.56 per cent of the total insect fauna) plus the number of other species not known to occur in Puerto Rico, 53 (10.07 per cent), makes up a total of more than 15 per cent of the overall insect fauna. These figures are in terms of what is actually known about the insects of Mona, since in all probability more insect species are yet to be recorded.

With this endemism and the unique conditions of the island due to its geographic isolation and climate, every effort should be made to maintain and preserve it as a

biological sanctuary. Endemism is also important in its flora and other animal life (mollusks, reptiles, crustaceans, mammals, etc.).

Together with its insect life we also have to consider the native and endemic flora. Preservation of the entire ecosystem in the area is of utmost importance. The zone that needs most to be cared for is the coastal plain from Sardinera to Uvero Beach, since it is in this particular zone where most of the interesting plant and animal life are found. Its destruction would be a great loss to the ecological features of Mona. The Island is a living laboratory for the study of biological sciences and as such it should be preserved for future generations.

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Apéndice: K

Assessment of Mona Island Avifauna

By

Herbert Raffaele
P. R. Department of Natural Resources

INTRODUCTION

A significant number of papers have been written presenting new information on the ornithology of Mona Island. A summary of ornithological excursions as well as visits of other persons who have made casual observations on the birdlife are included in Table 1. While most of these have been strictly annotated lists mentioning the status of occurrence of species and new records for the Island (with the notable exception of the Terborgh and Faaborg paper which primarily deals with extinction rates on islands) the present paper has a somewhat different goal. While an annotated list is included updating the status of the species that occur on Mona with many new additions, the main focus of this paper is to single out those birds whose status on Mona is in some way unique in relation to the avifauna of Puerto Rico as a whole. It also treats in detail the threat to these species, a separate section being devoted to sea birds which are particularly vulnerable. Measures that must be taken for the protection of Mona's avifauna are suggested.

II Nesting Sea Birds and Their Vulnerability, Breeding Habits and Management

Aside from the endemic wildlife that several offshore islands around Puerto Rico harbor (Mona contains more endemic animal species than all of Puerto Rico's other offshore islands combined including Vieques and Culebra), the most significant faunal feature of these islands is generally their sea bird colonies, some of which contain thousands of birds. While these sea birds are of economic importance in that they are excellent indicators for fishermen as to the location of fish schools, their prime value is in the tremendous aesthetic appeal that they have. Thousands of sea birds, particularly such exquisite and unique ones as the White-tailed Tropicbird, the boobies and Magnificent Frigatebird, circling over the rugged, precipitous crags of Mona make an awe inspiring sight.

Unfortunately there is a direct correlation between the remoteness and inaccessibility of an island to man and the numbers and types of sea birds that will be found breeding on it. The more remote the island the better the sea birds. There are several reasons for this. The first is that although sea birds may not taste good, their eggs do. The eggs, large and located all in one compact colony are an ideal target for poachers. Unless a government is willing to take the steps to patrol these breeding colonies, the birds will either move to a more remote area so that the human labor involved in getting to the eggs is not worth the profit, as was once the case on Desecheo and is still the case on Monito, or the birds will remain and face being wiped out.

A second reason rookeries are more spectacular, the more remote the island, is that regardless of the lack of intentional interference, such as poaching, some birds will not tolerate any type of disturbances, even seemingly harmless ones, around their nests. The Red-footed Booby needs much more privacy than the Brown Booby, and the Frigatebird probably is most sensitive of all. Boat traffic in the vicinity of the colony can lead to abandonment of the nests.

TABLE I

BIRD OBSERVERS AND DATES OF THEIR VISITS TO MONA AND MONITO

	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
W.W. Brown (Reported by Cory)	1892		XXXX	XX									
B.S. Bowdish	1901								XX				
P.H. Struthers	1921							X					
P.H. Struthers	1926						X	XX					
S.T. Danforth	1935				X								
H.A. Beatty (Reported by Bond)	1944								XXX				
V. Barnés	1943									X	X	X	X
V. Barnés	1944	X	X	X	X	X	X	X	X	X	X	X	X
V. Barnés	1945	X	X	X	X	X	X						
Edwards and Kuns (Reported by Leopold)	1953										XX		
F.J. Rolle	1960											X	
	1963					0							
C.B. Kepler	1969						X 0						
H.A. Raffaele	1971												X
H.A. Raffaele	1972							X					
J. Terborgh and Faaborg	1972		X										

NOTES:
1) An (x) refers to observations made on Mona; an (0) to observations on Monito.
2) Forester, Dr. Frank Wadsworth and Fishery Biologist Donald Erdman, have made numerous trips to Mona and both have contributed their notes on the birdlife there.
3) Ricardo Cotte was stationed on Mona as a biologist for the P.R. Fish and Wildlife Service from 1957 – 1960 during which time he made casual observation of the birds there.
4) Marcelino Marcial succeeded Cotte as a biologist on Mona. He visited the Island on the average of a few days per month from 1961 – 1970.

Another problem with these colonial nesters is that frequent disturbances which cause the adults to leave the nests temporarily can lead to tremendous losses as a result of predation by Laughing Gulls and Frigatebirds which constantly patrol over nesting colonies searching for unguarded eggs or chicks.

A final threat to sea birds, also unintentional, but invariably caused by man, is his introduction, wherever he goes, of cats and rats. On Mona the greatest problem would be rats. These are great destroyers of eggs, and species such as the Brown Booby and Audubon's Shearwater which, nesting on the ground and in burrows, are absolutely helpless prey. Rats are even on Monito where their main food source must be bird eggs and chicks. Probably the only thing that keeps rats from destroying these colonies, particularly on Monito, is that they starve in the nonbreeding season and their numbers are so reduced by the following season that they do not have the numbers to cause a disastrous effect on the colony. A paper by C.B. Kepler on predation by Polynesian Rats on the Laysan Albatross, another colonial nesting sea bird, gives a clear illustration of the helplessness of most sea birds. Kepler and other workers on Laysan Island frequently encountered injured birds and noticed many dying, or dead adults with gaping wounds on their backs, the lungs or thoracic cavity often being exposed. One night Kepler found a Laysan Albatross sitting on a plain. The following is his narrative:

> *As I approached rats fled from my flashlight beam. The bird had a large wound on its back. I shut out my light and sat down to watch, waiting a few moments before shining the headlight again on the albatross. When I did so, many rats scampered off his back where they had been feeding. Sitting quietly, with the light on, I could see rats approach the live bird, crawl upon his back, and feed on the exposed flesh. Every now and then the bird would twitch, turn back to try to get the rats, and then look forward again. There were over 20 rats feeding on the bird when I left. It was dead the following morning.*

While rat predation on Mona and other offshore islands no doubt occurs, though probably in a form other than that described for Laysan Island, we can count on it being augmented so that it would become a serious threat if the human population on Mona were to increase greatly. This is because the amount of man's wastes would increase thus supplying food for the rats which in turn would increase and prey to a more substantial degree on the sea birds.

Obviously Desecheo and Monito, by virtue of the diversity and quality of the species that nest or have nested there (the Desecheo colonies have virtually been wiped out by the introduction of monkeys), are the most outstanding areas in Puerto Rico for breeding sea birds, particularly Pelicaniformes. The cliffs of Mona, which provide a less remote, but new type of habitat, run close behind of the seven species of the order Pelicaniformes that breed in Puerto Rican waters, three nest exclusively among these three islands and two others have far and away their largest breeding colonies there.

When it comes to destroying a large sea bird rookery the question is always presented, "Won't they go someplace else? " The answer to this varies from species to

species and is unclear in most cases. The Audubon's Shearwater which was heavily fed upon by persons living on Mona was probably wiped out, or nearly so, without the species relocating. As long as the nesting burrows and rock crevices were not destroyed the species kept on nesting without ever realizing its dilemma. The Bermuda Petrel, a closely related species, is another case in point. This shearwater used to be the most abundant pelagic species breeding in the Bermuda Islands. It was good to eat and heavily exploited. One night's bag, probably in the 1500's, was said to have contained 4,000 birds. The bird could not adjust by moving to a new island and became so rare that one was not seen for 300 years. Recently the species was rediscovered and a small population survives precariously. The other shearwaters which depended on the Bermuda Islands for nesting, among them the Audubon's Shearwater, also did not relocate. As a result their populations have been greatly reduced.

In the case of the boobies we have a local example. In reaction to the monkey introduction on Desecheo in 1966 about half of the Red-footed Booby colony of that island has relocated to the most remote portions of Mona, though still not as removed as its former site on Desecheo. The other half of the population appears to be still trying to nest, though unsuccessfully, on Desecheo. This portion of the former colony may simply perish. In the case of the Brown Booby, whose population on Desecheo was estimated in 1927 at 15,000 individuals, none remain breeding on said island and they have not moved to any other island in Puerto Rican territory. Whether they have all expired, or moved to another island in a totally different region is not known.

While the situation of birds unable to relocate is extremely critical, and we apparently have several in this category, those species which do have the adaptability to search out another remote island uninhabitated by man also have a grave problem. There are few such islands left. Man is reaching out to the most removed little islets in his conquest of the globe. The animal forms dependent on these islets have evolved with little pressure from predation and man's invasions are generally careless and devastating. Over 90 per cent of the extinct animals in the world were island forms. While the sea bird species found in Puerto Rican territory are not yet in danger of becoming extinct in the world, their total numbers throughout the tropics, to which they are confined, has no doubt dropped drastically in modern times and will continue to drop.

If one is concerned about protecting nesting sea birds, and they deserve protection, besides the other considerations previously mentioned one must know when they breed as that is the time when they are vulnerable and regulatory measures must be taken. While it is clear that the pelagic terns nest in the spring and early summer, the breeding of the Pelicaniformes that thrive in the area of Mona is variable and has never thoroughly been evaluated. Table II is included to show all the known nesting records in Puerto Rican territory of the five major Pelicaniformes of the Mona-Monito region. These data can be summarized as follows:

1. While-tailed Tropicbird — This species is the most consistant, primarily nesting in spring and early summer. It sometimes begins nesting as early as February, or continues to as late as August.
2. Blue-faced Booby — From the scanty evidence available for only one season, it

seems this species nested in fall or winter. If this booby is at all like the others of its family represented here the breeding season is no doubt variable

3. Brown Booby — This species breeds in winter and spring with nesting infre quently continuing into summer.
4. Red-footed Booby — This booby has been found nesting to a substantial degree in every season of the year though it appears to have a preference for winter
5. Magnificent Frigatebird — The Frigatebird seems to slightly prefer winter nesting though it commonly breeds in spring and summer.

It is clear from this information that the breeding seasons of these birds are generally so variable that one species or another would need protection through most of the year with the possible exception of the fall. This indicates that care of the sea bird population of Mona and Monito is certainly a full-time job.

With careful management and proper precautions the rookeries of Mona can be handled so that many more Puerto Ricans can come to enjoy them and scientists to study them, but it must be emphasized that this has to be done very cautiously.

DETAILS ON THE MOST IMPORTANT AVIFAUNA OF MONA AND MONITO

Audubon's Shearwater-*Puffinus lherminieri*: Barnés relates that he observed this shearwater on the barren cliffs of the northern side of Mona. While this sounds like an extraordinary habit for a shearwater there is no doubt that the bird does occur around Mona as it has been recorded offshore many times by biologist Donald Erdman, and geologist Clifford Kaye found many bones of this species in Cueva Negra behind Sardinera. A key question in relation to this species is does it nest on Mona? Kaye's indisputable evidence that the species was once eaten in great numbers by the Indians of the Island indicates that this seabird did once breed there. Audubon's Shearwaters spend all day out at sea and only come to land at night to attend nest burrows. It is only at this time that the Indians could have secured them. Apparently, the nesting of Audubon's Shearwater on Mona has been greatly reduced. However, it is certainly premature to think that it has been eliminated there. The bird continues to be sighted regularly off the coast of Mona. Also the remoteness and inaccessability of the north coast of Mona coupled with the nocturnal visitation of the species to underground burrows or cliff crevices and even this only in the breeding season makes it clear that the short visits to the Island of all ornithologists since Barnés who last saw the birds on land, are sorely inadequate for evaluating the status of the species. Monito, which because of its remoteness is even a more likely nesting area for Audubon's Shearwater than Mona, is one big question mark.

Audubon's Shearwater, the only representative of the family Procellariidae in Puerto Rico and the Virgin Islands, is fast becoming extirpated from its few nesting cays in the Virgin Islands as a result of overhunting or poaching. It may still occur as a breeding bird in Puerto Rico where it is most likely to survive on Monito or Mona. A specific attempt should be made to determine for certain the status of Audubon's Shearwater on Monito and Mona. To protect this Shearwater the former island as well as the north coast of Mona should be preserved in their natural state and human

TABLE II
BREEDING DATA ON THE RESIDENT PELICANIFORMES OF MONA AND MONITO

WHITE–TAILED TROPICBIRD

OBSERVER	DATE	OBSERVATIONS	INDICATIONS
J. Gundlach	April, 1873	Fresh eggs at Quebradilla	Spring breeding
W.W. Brown	February, 1892	Abundant and breeding	Winter breeding
B.S. Bowdish	July, 1900 and August, 1901	Saw them at Mona and Desecheo, but mentions nothing. Apparently he saw none.	Probable late winter and spring breeding
A. Wetmore	April, 1912	6-8 in breeding condition near Culebra	Probable spring breeding
Struthers	Late June and July, 1926	Hundreds at the height of nesting on Mona	Spring and summer nesting
S.T. Danforth	1920's	Breeding season at Guajataca cliffs is apparently April to July	Spring and summer breeding
H.A. Beatty	Aug., 1944	Only 15 per cent on Mona, evidently nesting	Summer nesting but probably just a few late birds
V. Barnés	May, 1944	Found a breeding colony on Mona	Spring breeding
P.A. Buckley	January and February, 1970	January doing display flights at Guajataca. Peak numbers in February.	Late winter and spring breeding
C.B. Kepler	June, 1971	Located 25 nests in the Culebra Group	Spring and summer nesting
H.A. Raffaele	July, 1972	Between 100 and 200 Tropicbirds along the Mona cliffs. A few appeared to land on cliffs and were probably breeding	Probable spring and summer nesting
		BLUE–FACED BOOBY	
C.B. Kepler	June, 1969	50 on Monito. Not breeding	Probably fall or winter breeding

BROWN BOOBY

OBSERVER	DATE	OBSERVATIONS	INDICATIONS
W.W. Brown	Feb., 1892	Found the bird nesting in abundance on Mona	Winter breeding
B.S. Bowdish	Aug., 1901	Abundant on Mona, but doesn't mention seeing nests.	Probable winter or spring breeding
A. Wetmore	June, 1912	Found 8,000-10,000 on Desecheo, many young nearly all caring for themselves.	Winter and spring breeding
A. Wetmore	March, 1932	Reports that Chapman Grant found colony in Fajardo Cordillera with eggs and 3/4 grown young.	Winter and spring breeding
P.H. Struthers	July, 1921	Many seen, but doesn't mention nesting on Mona.	Probable winter and spring breeding
P.H. Struthers	Jan., 1922	On Desecheo 2,500 seen. Many were nesting.	Winter breeding
P.H. Struthers	June, 1926	Done nesting on Mona and Desecheo.	Winter or spring breeding
S.T. Danforth	May, 1927	15,000 on Desecheo with nests. Most had young past downy stage.	Spring breeding
V. Barnés	March, 1944	Found a breading colony on Mona containing 87 nests having eggs and others young birds.	Spring breeding
H.A. Beatty	August, 1944	Saw none on Mona, but 300 adults and a few immatures on Monito with no sign of nesting.	Probable winter nesting
F.J. Rolle	Nov., 1960	Many seen on Mona, but no nests. A single bird was just out of the nest.	Could have nested any season but winter
F.J. Rolle	May, 1963	On Monito numerous breeding adults and immatures.	Winter and spring breeding

OBSERVER	DATE	OBSERVATIONS	INDICATIONS
C.B. Kepler	June, 1971	50 nests in Culebra Group well advanced	Spring and early summer breeding
H.A. Raffaele	July, 1971	Over 100 all on eggs on cay in Fajardo Cordillera. Their eggs had apparently been poached and they had begun to nest again.	Spring and early summer breeding. Same season as Kepler's record
H.A. Raffaele	Dec. 1971	15 nests with eggs and young at Cabo Norte. About 150 boobies seen.	Light winter nesting, possibly heavier in spring
H.A. Raffaele	July, 1972	No nests, but about 100 individuals seen.	Probably bred in winter

RED–FOOTED BOOBY

OBSERVER	DATE	OBSERVATIONS	INDICATIONS
A. Wetmore	June, 1912	2,000 on Desecheo. Young were grown	Winter and spring breeding season
P.H. Struthers	Jan., 1912	Found 200 nesting on Desecheo	Winter nesting
P.H. Struthers	July, 1926	These boobies were done nesting on Desecheo.	Nested any season but summer
S.H. Danforth	May, 1927	50 nests on Desecheo. Most young in juvenile plumage though some in natal down.	Probably tail end of winter plus spring breeding
H.A. Beatty	Aug., 1944	Saw none on Mona, but 500 on Monito, half of which were immature.	Winter and spring breeding
V. Barnés	Sept., 1943 to June, 1945	A common resident along the coast.	Too vague for evaluation
F.J. Rolle	May, 1963	Small groups noted on Monito	Probable winter nesting
C.B. Kepler	June, 1969	Several thousand on Monito including several nests.	Light summer breeding

OBSERVER	DATE	OBSERVATIONS	INDICATIONS
H.A. Raffaele	Dec., 1971	700 nests in all stages at Cabo Norte on Mona in one colony. About 700 birds at Desecheo, but no nesting. Apparently inhibited by monkeys.	Fall and winter breeding
H.A. Raffaele	July, 1972	About 3,000 at Cabo Norte. 10-15 on nests and about 10 others carrying sticks or breading them off trees. Apparently nesting was beginning.	Summer and Fall breeding

MAGNIFICENT FRIGATEBRID

OBSERVER	DATE	OBSERVATIONS	INDICATIONS
B.S. Bowdish	June, 1900	One young in full plumage, but unable to fly was taken on Desecheo. Frigatebirds breed on Mona and Desecheo according to Bowdish, but he gives no dates.	Spring breeding
A. Wetmore	June, 1912	175 adults nesting on Desecheo. Most nests had young 3/4 grown.	Spring, and early summer breeding
P.H. Struthers	July, 1921	30 seen on Mona, no mention of nesting.	Probable winter breeding
P.H. Struthers	Jan. 1922	300 on Desecheo. Almost all nesting.	Winter breeding
P.H. Struthers	June, 1926	Rookeries on Mona abandoned.	Probable winter breeding
S.T. Danforth	April, Aug., 1927	Cayo Enrique at La Parguera. 60 nests with one young each from newly hatched, to ready to fly. In August many nests with good sized young.	Winter, spring and summer breeding

OBSERVER	DATE	OBSERVATIONS	INDICATIONS
S.T. Danforth	March, 1928	Cayo Enrique – Same conditions as April, 1927.	Winter and spring breeding
V. Barnés	March, 1943	Large breeding colonies on Mona. In one colony of 32 nests most had eggs, 5 had young.	Late winter and spring breeding
H.A. Beatty	Aug., 1944	Doesn't mention whether there was nesting on Mona, though it appears there wasn't. He did find 20 nests on Monito every one of which had a single nestling.	Summer breeding
F.J. Rolle	Nov., 1960	Saw a few over Mona (by this time the Mona colonies may have been abandoned as suggested by Beatty's and Raffaele's observations)	Inconclusive
F.J. Rolle	May, 1963	15 circling over Monito	Probable winter breeding
C.B. Kepler	June 1969	300 pairs on Monito	Probable fall winter breeding
H.A. Raffaele	Dec., 1971	About 75 off coast of Mona, but no nesting. However hundreds could be seen circling over Monito all day where nesting may well been going on.	Probable winter breeding

access to the area and disturbance of it should not exceed the level which presently exists. Patrolling of the nesting area during breeding may be necessary, as poaching is probably the greatest threat to the bird's survival; anything that would increase the rat population in this area should be strictly forbidden.

White-tailed Tropicbird — *Phaethon lepturus*: The most attractive and noteable feature of the birdlife of Mona Island is the breeding of the attractive White-tailed Tropicbird. This elegant sea bird with its streamer-like tail, a symbol of the tropics, nests by the hundreds and possibly the thousands, in cavities in the cliffs which surround Mona, particularly from just south of Cabo Barrionuevo around the north coast to the East Cape. Mona supports by far the largest population of these birds in Puerto Rican waters. The only significant breeding population on mainland Puerto Rico is in the cliffs around Quebradilla and Guajataca.

Certainly this impressive sea bird should be given a permanent refuge along the cliffs of Mona which it shares with several other nesting seabird species.

Brown Booby — *Sula leucogaster*: The Brown Booby is a common nesting bird on Mona whose numbers have never been estimated. Probably there are several hundred, or possibly even a few thousand on Mona and Monito.

Alexander Wetmore in 1912 found a minimum of 8,000 to 10,000 Brown Boobies nesting on Desecheo Island and Danforth 15,000 in 1927. This population apparently remained relatively stable until the introduction of Rhesus Monkeys onto that island in July of 1966. Since that time no Brown Boobies have been noted breeding on Desecheo and there is clear evidence that egg destruction by monkeys is the cause of their demise. As the monkeys have not been gotten off, in the near future, the fate of the Brown Booby on that Island is extremely precarious. It appears the population has not shifted to new nesting sites on Monito and Mona, as has happened to some extent with the Red-footed Booby. It is likely to extirpate itself if it continues to attempt to breed on Desecheo with no nesting success. The birds hopefully have moved to a completely new region. Should the monkeys be eliminated from Desecheo in the near future it is possible that the Brown Boobies there can return to their past numbers, but the chance of this booby recuperating becomes greatly reduced with the passage of time.

At present, until the problem at Desecheo is resolved, one must consider Mona and Monito the prime breeding grounds of *S. leucogaster* in Puerto Rico. The only other known nesting areas in Puerto Rico are a cay in the Culebra Group that supports about 50 nesting pairs of Brown Boobies and another cay in the Fajardo Cordillera that supports approximately 100 pairs of breeding boobies.

The cliff edges bordering the plateau, particularly along the north coast, the cave months facing out toward the sea, the huge boulders lying adjacent to Mona that are fragments that have fallen off the cliff face, and Monito are the key breeding areas of the Brown Booby, and all these sites should be preserved and access to them limited to protect this seabird.

Red-footed Booby — *Sula sula*: Based on past reports it seems that the Red-footed Booby was never surely known to breed on either Mona or Monito though Beatty, as reported by Bond, found 500 adult and immature birds on Monito in August 1944 and Barnés refers to the species as being a common resident along the

Mona coast. In all probability these birds were vagrants from the nearby breeding colony at Desecheo which Wetmore in 1912 reported to contain about 2,000 nesting birds.

In December 1971 the writer found 500-700 nesting pairs of Red-footed Boobies in the trees at Cabo Norte, probably the most remote and rugged section of Mona, and also saw hundreds of them nesting on Monito. Two days prior to this the writer had been on Desecheo where he found no less than 600 Red-footed Boobies feeding offshore, and resting in the trees where nests were found, but in sharp contrast to Mona, none of these nests were active. They were all abandoned.

It is likely that this circumstance can be directly related to the introduction of Rhesus Monkeys on Desecheo. The Red-footed Booby cannot breed successfuly on Desecheo in the presence of the monkeys and over two-thirds of the population has apparently shifted to Mona and Monito to nest. The rest of the birds have not been able to adapt and are confusedly milling around their old nesting site.

With the elimination of Desecheo as a breeding site Mona and Monito become the only nesting areas of the Red-footed Booby in Puerto Rico.

It appears that the Red-footed Booby is much less tolerant of human interference than the Brown Booby, as shown by the fact that it nests only in the remotest possible areas. Access to Monito and Cabo Norte must be kept at an absolute minimum to insure the survival of a Red-footed Booby colony in Puerto Rico.

Blue-faced Booby- *Sula dactylatra*: The recent discovery by Dr. Cameron Kepler of 50 Blue-faced Boobies breeding on Monito is the second sight record, and the first observation of a significant flock of this species in Puerto Rico. This flock, representing the rarest of boobies in the Caribbean, probably breeds and should be protected. To do this Monito must be kept in its present state.

Magnificent Frigatebird – *Fregata magnificens:* While frigatebrids used to nest at a cay off La Parguera and at Desecheo these colonies have been driven away, the former by increased boat traffic and the latter by the monkeys on that island. The species has been reported by several observers as being a breeding bird on Mona and Monito and Barnés pinpointed a colony on Mona as being near Cueva del Gato.

This species is one of the most sensitive to man's intrusions. It can only breed in the remotest of areas and even a minor increase in human traffic in the vicinity of its breeding sites can lead to abandonment of that island by the colony. The portions of Mona where this bird breeds, which are no doubt primarily along the remote north coast, and Monito Island must be kept as they are with no increased interference if this regal sea bird, one of the most graceful aerialists in the bird world, is to remain as a breeding bird in Puerto Rico's waters.

Bridled Tern – *Sterna anaethetus*: This pelagic tern was said by Bowdish to breed commonly along the cliffs of Mona, and Barnés saw them commonly along the coast, but did not say they bred there. In 1912 Wetmore reported 1,500 breeding on Desecheo, but in June of 1970 Kepler found not a single bird breeding on the main island of Desecheo and only a few pairs nesting on small islets offshore. Apparently the monkeys have eliminated the Desecheo breeding colony. The writer in a visit to Mona in early July 1972 saw less than 10 Bridled Terns and no signs of breeding.

Apparently the birds have not switched from Desecheo to Mona to breed. What has happened to the Desecheo population is presently a mystery. The cliffs of Mona and Monito should again be checked earlier in the spring for breeding Bridled Terms as Mona may now support our major colony. More importnat, the monkeys should be gotten off Desecheo. The only significant remaining colony in Puerto Rico contains 350 nests and covers 2 cays in the Culebra Group.

Sooty Tern – *Sterna fuscata:* The Sooty Tern, another pelagic species, comes to Mona in the spring as does the Brown Noddy, to nest in crevices in the cliffs. It is a common nesting bird on Mona & Monito numbering in the thousands. Kepler found about 5,000 nesting on Monito alone. The main colony of this species in Puerto Rico is on Culebra. *S. fuscata* in the book "Rare and Endangered Fish and Wildlife of the United States" is considered peripheral which means rare within the boundaries of the United States, but common elsewhere.

Brown Noddy – *Anous stolidus:* Like the Sooty Tern, the Brown Noddy is considered peripheral in the United States. There are three main colonies in Puerto Rico where the birds breed by the hundreds. These are Mona and Monito, cays of the Culebra Group, and islets of the Fajardo Cordillera. The main breeding area for the Brown Noddy used to be Desecheo where 2,000 were known to nest, but practically the entire colony has been displaced by the monkeys on that island. As a result of this the remaining breeding sites, which include the cliffs of Mona and Monito, become that much more important in terms of preserving the Brown Noddy as a breeding bird in Puerto Rico.

White-crowned Pigeon – *Columba leucocephala*: Struthers (1927) lucidly describes the past status of the White-crowned Pigeons which he found nesting on the plateau by the thousands in early July 1926. "At sunrise and sunset flocks numbering as high as 500 individuals were seen approaching Mona from the direction of Santo Domingo." Unfortunately this abundance of birdlife was the basis of another observation related to me by Dr. Wadsworth. On one trip to Mona over a decade ago he had encountered hunters blazing away at White-crowned Pigeons until their gun barrels got too hot to hold. The hunters had killed hundreds of pigeons just in that one area and they had long since run out of ice for preserving the birds.

Today, only several hundred White-crowns nest on Mona. This decrease could be the result of habitat destruction in the Dominican Republic, where many of the birds winter, as well as the effects of overhunting on Mona. White-crowned Pigeons stay on Mona to nest approximately from May to August at which time they return to the Dominican Republic. Both Brown and Rolle found the species in winter, the latter author remarking that it was numerous. Some birds obviously winter on Mona, the number possibly fluctuating from year to year.

These pigeons generally nest in huge colonies, making them easy to protect yet, at the same time, easy to slaughter. Barnés mentions the birds nested throughout the Island on the coastal plain as well as the plateau. Probably they had specific areas in which they concentrated, though this may have varied annually. Ricardo Cotte related to me that during his work on Mona from 1957-1960 he found small nesting aggregates of White-crowns on the coast between Playa de Pájaro and the lighthouse, at the Bajura de los Cerezos, at La Carmelita south of Cabo Barrionuevo where the

coastal plain meets the cliff, and at Las Palmeras by the cliffs near Uvero.

The White-crowned Pigeon is a favored game species that is suffering a great reduction in numbers throughout its range. Mona is the prime breeding area for this bird in Puerto Rico, but because of the White-crown's great flying ability we must not only worry about protecting Mona as a breeding ground but also about the practices in the Dominican Republic relating to this bird. Until steps are taken to stop the constant decreasing of the White-crowned Pigeon population in Puerto Rico it is considered an endangered species.

Red-necked Pigeon – *Columba squamosa:* The Red-necked Pigeon reported by several authors as a common nesting bird on Mona and Barnés notes that it comes in March and leaves in August as the White-crowned Pigeon does. However, Rolle found 35 in November, so the species no doubt winters, even though its numbers may be reduced. Cotte is the only worker that reports –in conversation– that the Red-necks actually outnumber the White-crowns on Mona.

Surprisingly some observers, including Struthers and Beatty, both of whom visited Mona during the summer, noted no Red-necked Pigeons. It could be that this species is extremely variable in its habit of using the Island as a nesting ground, though this would seen odd.

The Red-necked Pigeon is an important game bird in Puerto Rico. Whether its numbers have decreased in the last decade is not known as there is little recent data on its status. Red-necks do not nest in close knit colonies like the White-crowns. They are generally more dispersed and most likely prefer the more heavily wooded areas of the plateau for nesting. Much more careful observations should be made of this and the other hunted pigeons and doves by Fish and Wildlife personnel stationed there so that we will be aware of any adverse effects on the abundance of these birds. Fortunately, this year some work along that line has been begun.

Zenaida Dove – *Zenaida aurita*: This dove used to be an abundant permanent resident on Mona which nested in all seasons of the year. While the species is still common it can hardly be considered abundant. The reduction is no doubt the direct result of hunting pressure. While the Zenaida Dove has withstood hunting stress better than any other animal native to Puerto Rico it is still critical that we carefully monitor this bird so that better management practices can be established, which will result in better conservation of the species while at the same time increasing the crop for hunters. Much too little is being done along this line at present if we are to continue hunting in Puerto Rico. The recently established White-winged Dove *(Zenaida asiatica)* and Mourning Dove *(Zenaida macroura)*, both game birds, are also in need of study.

Yellow-shouldered Blackbird – *Agelaius anthomus monensis:* This is probably the most unique and interesting bird on Mona, being one of two subspecies of this blackbird which is endemic to Puerto Rico. The other subspecies is confined to the main island. It is very possible that this species is endangered in Puerto Rico proper and on Mona. Since the turn of the century, when the Yellow-shouldered Blackbird was common throughout the coastal plain of Puerto Rico, it has become practically restricted to the xeric southwestern corner of the Island. This is probably a result of altered land use in the coastal plain. Recently, an additional pressure is threatening

this bird. The Glossy Cowbird (*Molothrus bonariensis*), a recent arrival to Puerto Rico, is a nest parasite as detailed below. It associates very closely with the Yellow-shouldered Blackbird and if it is parasitizing that species' nests it could cause a precipitous decline in that bird's population that may ultimately lead to extinction. Island birds have difficulty adapting to this kind of competition from continental species such as the Glossy Cowbird. Already this parasite has nearly caused the extinction of the endemic subspecies of the Yellow Warbler (*Dendroica petechia petechia*) on Barbados.

In December, 1972 a flock of about one dozen Glossy Cowbirds was reported for the first time from Mona, thus posing a great threat to the few hundred Yellow-shoulders that inhabit that island.

It would be desirable, though practically impossible, to eliminate, or at least control the numbers of Glossy Cowbirds on Mona. At least immediate stops should be taken to study and carefully document the interaction of these two icterids, as this is a dynamic and unique situation that can be followed from its outset. Even without the competition from the Cowbird the Yellow-shouldered Blackbird on Mona deserves study in its own right because of its singular habits. Unlike its closest relatives which are heavily dependent on swamps, this bird survives in the arid scrub of the Mona plateau as well as on the coastal strip. It also has the extremely interesting habit of diving over the cliff face into forceful northeasterly winds for some unknown reason, possibly to feed on the fruits of the scanty plant life clinging to the cliff face.

Glossy Cowbird — *Molothrus bonariensis*: Aside from a single record of the Glossy Cowbird in Vieques around 1860 the first time this species was seen to be established in Puerto Rico was 1955 when a large flock was found near Las Croabas. In recent years the species has spread so that its population center seems to be in the southwest, centered around La Parguera. In December 1972 the Glossy Cowbird was reported from Mona.

It is of particular importance that the behavior of this species be studied as it is brood parasitic. That is, instead of building a nest of its own, the female Cowbird waits for the correct moment and lays its egg in the nest of another bird. The female of the host species usually can't discern the difference between her own and the Cowbird's offspring and so rears the nestling Cowbird as one of its own. Unfortunately the survival of the nestling Cowbird is often at the expense of the lives of some, or all of the legitimate brood.

On Islands such as Puerto Rico and Mona the avian populations have never before experienced this type of stress and have not evolved mechanisms to cope with it. Worse than that, island populations are so small that they can be wiped out before a portion of them become adapted to handle the new threat.

It is critical that we learn the preferred hosts of the Glossy Cowbird and determine what deleterious effects they might be experiencing so that steps might be taken to thwart the extinction of some native bird. Certainly the Yellow-shouldered Blackbird, as an unique, endemic form closely associated with the Cowbirds, is the species we must be most concerned with protecting. The endemic Mona population, in particular because it is no more than a few hundred birds, needs immediate moni-

toring if we hope to insure that some day in the near future we don't find that it has totally disappeared.

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Annotated List of the Birds of Mona

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
1.	Audubon Shearwater	*Puffinus lherminieri*	Occurs offshore mostly in spring and probably nests at least on Monito. Recorded by Barnés on cliffs. Erdman saw them offshore March 1960.
2.	Leach's Petrel	*Oceanodroma leucorhoa*	Observed by Barnés following fishing boats. A winter visitant to our offshore waters.
3.	Wilson's Petrel	*Oceanites oceanicus*	Spring visitant to offshore waters. Reported by Marcial.
4.	White-tailed Tropicbird	*Phaethon lepturus*	Common nester in spring and summer in cliff crevices. Mona is the main nesting area of this bird in Puerto Rico.
5.	Brown Pelican	*Pelecanus occidentalis*	Nested for a short time, now just a year round resident.
6.	Blue-faced Booby	*Sula dactylatra*	Probably nests on Monito as reported by Kepler and seen offshore by Erdman and near Desecheo by Dr. Catesby Jones. These are the only observations for Puerto Rico.
7.	Brown Booby	*Sula leucogaster*	Common nester on cliff edges; nests year round.
8.	Red-footed Booby	*Sula sula*	Mona and Monito are the only nesting areas of this species in Puerto Rico. Their nesting season appears to be variable. On Mona the colony is at Cabò Norte.
9.	Magnificent Frigatebird	*Fregata magnificens*	Only sure nesting site remaining in Puerto Rico is Monito. They may still nest along the north coast of Mona. Nesting is primarily in spring, but variable.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
10.	Great Blue Heron	*Ardea herodias*	One recorded from pond near Sardinera 12/9/71 by Raffaele, Wadsworth and botanist Roy Woodbury.
11.	Green Heron	*Butorides virescens*	Reported by Marcial.
12.	Cattle Egret	*Bubulcus ibis*	Reported first by Wadsworth; Erdman saw several at Sardinera May 1960. 2 later seen by Raffaele and Wadsworth 12/9/71 and 12/11/71 on SW and E coasts. Terborgh and Faaborg saw one at Sardinera 2/5/72 and Raffaele another one at Sardinera 7/2/72.
13.	Louisiana Heron	*Hydranassa tricolor*	Reported by Marcial.
14.	Black-crowned Night Heron	*Nycticorax nycticorax*	Reported by Marcial.
15.	Yellow-crowned Night Heron	*Nyctinassa violacea*	Seen by most observers, Barnés and Beatty found it common and Beatty found a nestling.
16.	American Bittern	*Botaurus lentiginosus*	Leopold reports that Edwards and Kuns collected a specimen on Mona Oct. 3, 1953. No other details are given.
17.	Fulvous Tree Duck	*Dendrocygna bicolor*	Reported by Marcial.
18.	West Indian Tree Duck	*Dendrocygna arborea*	Kepler reported a stray bird standing in road, June 1970.
19.	Blue-winged Teal	*Anas discors*	Accidental on Mona. Barnés collected one in the mangrove swamp SE of Sardinera 11/5/44. Erdman saw 2 Oct. 1962.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
20.	Sharp-shinned Hawk	*Accipiter striatus*	Terborgh and Faaborg report observing an immature bird carefully on 2/5/72. This was probably a North American migrant, a bird which probably sporadically visits Puerto Rican territory.
21.	Osprey	*Pandion haliaetus*	An irregular winter visitant to the south coast of Mona. Reported by Bowdish, collected by Barnés 11/12/44, and seen by Wadsworth various times and Raffaele 12/11/71. Erdman saw one 3/20/60 and another 1 Oct. 1962.
22.	Sparrow Hawk (Dominican subspecies)	*Falco sparvarius dominicensis*	First reported by Danforth in 1935, this bird has been seen regularly since. It is now a nesting resident. This species was apparently blown to Mona from Hispaniola following the hurricane that hit that island in 1926. Mona has the only representatives of this sub-species in Puerto Rico.
23.	Peregrine Falcon	*Falco peregrinus*	Danforth reported 4 birds in April 1935, Rolle had a report of one in Nov. 1960 and Raffaele and Wadsworth saw one in December 1971. This species is an irregular winter visitant. Erdman saw one bird March 20, 1960.
24.	Red Jungle Fowl	*Gallus gallus*	Tarborgh and Faaborg state that personnel of the U.S. Coast Guard and P.R. Fish and Wildlife Stations told them domestic fowl had been on Mona for many years and that wild flocks inhabit dense growth in the central portion of the plateau.

COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
25. Bobwhite	*Colinus virginianus*	The Puerto Rico Fish and Wildlife Service released 100 pairs of this quail on Mona 7/14/71. Terborgh and Faaborg flushed one at Sardinera in a grassy clearing 2/1/72. It is possible that this game bird may establish itself on Mona in the absence of Mongooses.
26. Sora Rail	*Porzana carolina*	Barnés collected a female in poor condition. This species may infrequently winter on Mona, but it is unlikely.
27. Common Oystercatcher	*Haematopus ostralegus*	McCandless reports the bird as being irregular on Mona. He apparently noted the species there on a trip in the 1950's.
28. Killdeer	*Charadrius vociferus*	Barnés collected 2 specimens, one on 6/5/43 and the other 6/5/44. Apparently the bird is an occasional visitant.
29. Black-bellied Plover	*Squatarola squatarola*	Barnés saw a flock of 11 on the beach at Sardinera and 2 were collected 10/21/44. This bird is an occassional visitant to Mona in winter, fall and spring.
30. Ruddy Turnstone	*Arenaria interpres*	Danforth recorded 12 at Uvero Beach April 1935. The bird is, no doubt, an occasional visitor in winter, spring and fall.
31. Common Snipe	*Gallinago gallinago*	Reported by Marcial. A rare visitant in winter, spring and fall.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
32.	Spotted Sandpiper	*Actitis macularia*	Reported by several observers, Barnés states that large numbers of this species arrive on Mona during migration associated with other sandpipers. It is most common along the coast from Sardinera to Uvero and also at Playa de Pájaro.
33.	Solitary Sandpiper	*Tringa solitaria*	Barnés found it a common winter migrant along the coast and sandy beaches. He collected two specimens in the mangrove south of Sardinera 12/10/44.
34.	Greater Yellowlegs	*Tringa melanoleuca*	Barnés collected one on dirt road between Sardinera and Uvero 12/10/44, noted 5 at Sardinera 11/10/44, and 2 at Playa de Pájaro 11/27/44. This species is an uncommon winter, spring and fall visitant.
35.	Lesser Yellowlegs	*Tringa flavipes*	Barnés noted 22 individuals 11/10/44 in mangroves at Sardinera and classified the bird as a common winter migrant. It no doubt also occurs in spring and fall.
36.	Least Sandpiper	*Calidris minutilla*	Struthers noted 2 on Mona 7/15/21 and Barnés indicated it was common in winter along the beaches. He collected 2 specimens.
37.	Semipalmated Sandpiper	*Calidris pusilla*	Bowdish collected one specimen and Barnés found it a common winter migrant inhabiting the sandy beaches. He collected a male 11/5/44.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
38.	Stilt Sandpiper	*Micropalama himantopus*	Rolle reported an individual seen by Greer, a geologist of the U.S. Soil Conservation Service, near Playa Sardinera 11/6/60.
39.	Sanderling	*Crocethia alba*	An uncommon migrant, Barnés collected 3 birds at Playa Sardinera 11/12/44. This constitutes the only record.
40.	Black-necked Stilt	*Himantopus himantopus*	Struthers found this species common about the lagoon north of Playa Sardinera and thought the flock may have nested. The Black-necked Stilt is apparently a periodic visitor to Mona.
41.	Laughing Gull	*Larus atricilla*	A common resident at Mona during the summer. Kepler found the first nests known to Puerto Rico on Monito. Barnés' notes seem to indicate he also saw the species during winter, when it would be less common.
42.	Bridled Tern	*Sterna anaethetus*	Said by Bowdish in 1901 to be a common breeding bird on Mona, no one has since seen it nesting, though Barnés reported it as common in adjacent waters. It appears that if they breed on Mona it is in small numbers. One would expect that the disturbance of the large Desecheo colony by monkeys recently would have caused the birds to shift to Mona, but this does not seem to be the case.
43.	Sooty Tern	*Sterna fuscata*	Kepler located 5,000 nesting on Monito. Struthers found this a common breeding bird on Mona and Raffaele observed approximately 500 that appeared to be nesting on 7/5 and 6/72. Other observers saw the birds only out at sea.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
44.	Royal Tern	*Thalasseus maximus*	Barnés collected one specimen at Playa de Pájaro 11/6/44, noted 3 individuals at Sardinera 12/12/44 and 7 at Uvero 3/23/44. McCandless claims the bird nests on Mona, but gives no details.
45.	Brown Noddy	*Anous stolidus*	This tern breeds commonly on Mona in the spring and summer numbering in the hundreds and possibly thousands. Barnés found a large colony on 6/12/43 on the north coast near Cueva del Toro and another one at La Esperanza 5/23/44. With the destruction of the large breeding coloney on Desecheo by monkeys, Mona becomes the single largest breeding area for this species in Puerto Rico.
46.	White-crowned Pigeon	*Columba leucocephala*	Once an abundant nesting resident from May to August its numbers have dropped from the thousands to the hundreds. Some winter on Mona, but it appears that most go to the Dominican Republic. The White-crowned Pigeon is a valuable game bird, but it is overhunted. Its numbers have dropped drastically in Puerto Rico and it is considered endangered. Mona is the main breeding ground of this bird in Puerto Rico.
47.	Red-necked Pigeon	*Columba squamosa*	The Red-necked Pigeon is a common summer nesting bird on Mona that is less common in winter. It is an important game bird and its abundance should be monitored.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
48.	Zenaida Dove	*Zenaida aurita*	This dove is a common permanent resident on Mona where many persons come to hunt it as well as the other doves and pigeons. It nests in all seasons. It may be less abundant than in the past, but it is still common
49.	White-winged Dove	*Zenaida asiatica*	First reported by Barnés this species is gradually becoming more common on Mona where it comes to nest in spring and summer. It is a hunted species.
50.	Mourning Dove	*Zenaida macroura*	The only published record governing this species on Mona is by Bond where he relates that Beatty saw one adult and an immature bird. Cotte, in conversation, said this bird was common in clearings the year round. Hunters recently told me they saw a flock of 500-600 on Mona. This is in line with the bird's recent increase in Puerto Rico.
51.	Ground Dove (Mona subspecies)	*Columbina passerina exigua*	An endemic subspecies to Mona, this bird is common.
52.	Ruddy Quail Dove	*Geotrigon montana*	Bowdish found this bird very common on Mona and Struthers collected a specimen. It has not been seen since and is presumed extinct there.
53.	Key West Quail Dove	*Geotrygon chrysia*	Bowdish reports that he saw this species on Mona, but it has not been seen since. Apparently now extinct on Mona.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
54.	Hispaniolan Parakeet	*Aratinga chloroptera maugei*	Formerly an endemic subspecies occurring on Mona and possibly Puerto Rico., but now extinct. The last specimen was taken by W.E. Brown Jr. for Cory Feb. 25, 1892.
55.	Mangrove Cuckoo	*Coccyzus minor*	A common permanent resident on Mona.
56.	Yellow-billed Cuckoo	*Coccyzus americanus*	Bowdish collected one on Mona in 1901 and Rolle observed another 11/5/60 on the Plateau 1/2 mile from the lighthouse. A rare migrant on Mona, possibly nests.
57.	Smooth-billed Ani	*Crotophaga ani*	The Ani apparently became established on Mona between Struthers' last visit in 1926 and Danforth's in 1935 when he discovered the bird there. It was probably blown to the Island by the 1930 hurricane that carried the Sparrow Hawk from Hispaniola to Mona. The bird nested and thrived fairly well until after Rolle's visit in 1960. It is now quite rare if not already extirpated as Terborgh and Faaborgh saw only one flock of 2-3 individuals and Raffaele saw none in a day trip around Mona in July 1972.
58.	Chuck-will's-widow	*Caprimulgus carolinensis*	On 2/21/72 Cotte collected a specimen. This bird is transient through Mona, or possibly a rare winter resident. Botanist Roy Woodbury reports seeing one. This is the only other record for this species on Mona.
59.	Common Nighthawk	*Chordeiles minor*	Rolle reports seeing one individual on 5/31/63. This bird is a rare migrant over Mona.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
60.	Black Swift	*Cypseloides niger*	One bird of this species was seen clearly by Raffaele flying over the *Casuarina* forest at Sardinera 6/30/72. A rare vagrant to Mona.
61.	Belted Kingfisher	*Ceryle alcyon*	The 7/21/21 sighting of a pair of King-fishers on Mona is the earliest summer record for the entire West Indies were the bird winters. This is an uncommon visitant to Mona.
62.	Yellow-bellied Sapsucker	*Sphyrapicus varius*	Frank Wadsworth first noticed the numerous signs indicating that this woodpecker occurs on Mona. Terborgh and Faaborg captured a specimen 2/4/72. The Sapsucker is an uncommon winter visitor to the Island.
63.	Grey Kingbird	*Tyrannus dominicensis*	A relatively common permanent resident on Mona. Struthers claimed to have seen 10 Loggerhead Kingbirds *(Tyrannus caudifasciatus)* on Mona and no Grey Kingbirds. His record no doubt refers to the former species.
64.	Lesser Antillean Pewee	*Contopus latirostris*	Marcial reports observing this flycatcher on Mona. Apparently a stray.
65.	Caribbean Martin	*Progne dominicensis*	A fairly common summer resident on Mona.
66.	Cave Swallow	*Petrochelidon fulva*	Beatty reported a bird of this genus on Mona during his work. Marcial later noted Cave Swallows and Raffaele noted a single bird 7/1/72. This species is an occassional visitant, or possibly a rare permanent resident on Mona.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
67.	Barn Swallow	*Hirundo rustica*	Rolle was the first to report this species from Mona noting 6 birds above the plateau 11/5-6/60. – Raffaele and Wadsworth saw approximately 75 Barn Swallows on Mona 12/9 – 12/71 with flocks at the lighthouse and Uvero.
68.	Northern Mockingbird	*Mimus polyglottos*	Apparently a stray Mockingbird lived on Mona for four months prior to Nov. 1951 before being collected. It was prepared by Dr. Biaggi.
69.	Pearly-eyed Thrasher	*Margarops fuscatus*	The most common land bird on Mona, it is a permanent resident.
70.	Grey-cheeked Thrush	*Catharus minimus*	A single individual was observed by Wadsworth which constitutes only the second record of this accidental winter visitant from Puerto Rico.
71.	Red-legged Thrush	*Mimocichla plumbea*	Terborgh and Faaborgh report that several members of their party saw a lone bird twice on 1/31/72. This was apparently a stray individual.
72.	White-eyed Vireo	*Vireo griseus*	Terborgh and Faaborg report one sang daily in an Acacia thicket near their camp at Uvero. This is only the second report of this species from Puerto Rico the first being a record by Raffaele in San Juan 12/31/70. This bird's normal wintering range includes the Greater Antilles west of Puerto Rico. The White-eyed Vireo is a stray as far east as Mona and Puerto Rico.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
73.	Black and White Warbler	*Mniotilta varia*	Barnés refers to this warbler as a common winter migrant, though only one other observer has reported the bird. Specimens have been taken.
74.	Parula Warbler	*Parula americana*	This warbler is an uncommon winter migrant to Mona. Four observers having recorded it.
75.	Magnolia Warbler	*Dendroica magnolia*	Marcial first recorded it and Terborgh and Faaborg observed several specimens foraging in tree crowns on the coastal plain. This warbler is an uncommon winter visitant to Mona.
76.	Myrtle Warbler	*Dendroica coronata*	Barnés found this a common winter resident and collected three in the *Casuarina* forest east of Sardinera and once at Uvero.
77.	Yellow Warbler	*Dendroica petechia*	Marcial records this bird from Mona and Raffaele heard one sing at Cabo Norte 7/2/72. These records were probably of strays.
78.	Yellow-throated Warbler	*Dendroica dominica*	An uncommon migrant, Barnés collected one at Uvero 4/4/44. This is the only Mona record.
79.	Bay-breasted Warbler	*Dendroica castanea*	The only specimen of this species in Puerto Rico was taken by Edwards and Kuns on Mona 10/10/53. There are a few sight records to the species for western Puerto Rico. This species is a stray this far east in the West Indies.
80.	Prairie Warbler	*Dendroica discolor*	A fairly common winter visitant to the coastal plain of Mona, particularly in the *Casuarina* forest.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
81.	Palm Warbler	*Dendroica palmarum*	An uncommon winter visitant, Barnés, the only observer of this species on Mona, collected two in the *Casuarina* forest east of Sardinera 1/26/44.
82.	Cape May Warbler	*Dendroica tigrina*	An uncommon winter visitant. Terborgh and Faaborg netted two which consitutes the only Mona record.
83.	Black-throated Blue Warbler	*Dendroica caerulescens*	A rare winter visitant, Terborgh and Faaborg saw a fully plumaged male near Sardinera 2/5/72.
84.	Ovenbird	*Seiurus aurocapillus*	The first record for Mona was a male collected by Barnés in the *Casuarina* forest 4/4/44. Wadsworth and Raffaele saw a specimen near Sardinera Dec., 1971. This species is a rare migrant on Mona.
85.	Northern Waterthrush	*Seiurus noveboracensis*	Cory reports this species and Barnés collected one on 3/24/44 in the *Casuarina* forest. Wadsworth and Raffaele heard 4 Dec. 1971. The species is a rare migrant and possible winter resident.
86.	Louisiana Waterthrush	*Seiurus motacilla*	A specimen was collected by Bowdish 8/18/01. This waterthrush is a rare migrant to Mona.
87.	Connecticut Warbler	*Oporornis agilis*	A specimen was taken from Mona by Edwards 10/6/53. It is a very rare migrant through this area.
88.	Common Yellowthroat	*Geothlypis trichas*	Terborgh and Faaborg netted a male 2/3/72. This species is a very rare transient, or winter visitant on Mona.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
89.	Hooded Warbler	*Wilsonia citrina*	Terborgh and Faaborg netted a male on the coastal plain 2/3/72. This warbler is a trasient, or rare winter resident on Mona.
90.	American Redstart	*Setophaga ruticilla*	Barnés found this warbler to be a common winter migrant in the *Casuarina* forest and the coastal plain. Raffaele and Wadsworth noted three individuals 12/12/71 on the coastal plain. Erdman reported one Oct. 1962.
91.	Bananaquit	*Coereba flavelola*	Introduced by Marcial these birds are barely surviving on Mona.
92.	Scarlet Tanager	*Piranga olivacea*	A rare winter migrant Barnés collected a specimen 5/3/44. There are only 2 other records of this species for Puerto Rico. The bird is a rare transient in the West Indies most frequently passing through western Cuba.
93.	Glossy Cowbird	*Molothrus bonariensis*	Víctor Márquez of the P.R. Fish and Wildlife Service, and Dr. Manuel Vélez of the University of Puerto Rico, independantly reported to me that they had seen this species on Mona early in 1971. This parasitic bird could become a big problem for resident land birds. Its effects should be studied.
94.	Troupial	*Icterus icterus*	Introduced in 1967 by Marcial the bird still survives in small numbers Raffaele and Wadsworth having recorded 3 on the plateau 12/10/71.
95.	Yellow-shouldered Blackbird (Mona subspecies)	*Agelaius xanthomus monensis*	This blackbird, an endemic subspecies to Mona, is fairly common on the plateau and coastal plain, probably several hundred birds in total existing on the Island. Its future may be threatened by the Glossy Cowbird. Their interaction should be studied.

	COMMON NAME	SCIENTIFIC NAME	OBSERVATIONS
96.	Blue Grosbeak	*Guiraca caerulea*	The only record of this species for all of Puerto Rico was a specimen taken by M. L. Kuns 10/3/53 on Mona. This bird generally winters in Central America and further west in the Greater Antilles and Bahamas.
97.	Grasshopper Sparrow	*Ammodramus savannarum*	Reported by Marcial. Apparently a stray.